7

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Book 7

Home
Phone WH-6-4455

Wilfrid Rall
11420 LUXMANOR RD
ROCKVILLE, MD.
20852

70¢

Office Phone
496-4325

Office Address
Bldg 31 Rm 9-A-17
National Insts. of Health
Bethesda, Md.
20014

Research & Computation Diary

(Continued from Book 6)

This begins August 3, 1965

& extends thru

See p. 60 for list of computation series

8/3/65

Just returned from 3 weeks at Bethany Beach.
While there, finished settling with Tom & Milton by telephone on "Dendro-Dendritic" revisions for "Experimental Neurology". Science did not accept.

Now, must concentrate upon slides for Tokyo and also figures for mitral cell paper. The drawings were left with art department before going to Bethany.
Figs. 5, 10 & 11 were done first, as requested, & I have today returned them for minor corrections.

List of figures, as of 7/6/65 & when working with Gordon

Gordon 1. Recording arrangement & schematic Golgi anatomy
Gordon 2. Full experimental series with histological drawing.
7/28/65 3. Periods I, II & III at four levels GL, EPL, MBL, GRL
To do 4. Spheres and Potential Divider
8/3/65 5. Intracell & Extracell at three levels for passive mitral
8/4/65 6. Theoret Series, ~~two~~ passive & two active.
7. Apparent velocity plot
8. Theoretical gradients at I early, peak late, I-II, II early, peak late
9. Experimental gradients
8/3/65 10. Theoretical granule reconstruction
8/3/65 11. Superposition

← dates taken to photography

Won't hurt to have a few extra slides. But must prepare them in time to be ready.

~~sent~~ this to photography in July for G-L, PL, MBL, ~~[illegible]~~ and came out clear, but now believe should have four levels.

8/3/65 Notes for slide sequence for Tokyo

(1) New slide to be made from Text-figs 1 & 2 of Phillips et al. or equivalent which shows recording conditions rel. to bulb. and shows mitral cell. Also makes clear origin of data.

(2) Periods I, II, III at three or four levels, with schematic mitral and granule cells. May need to use this slide twice during talk.

(3) ? slide showing sphere, cone and pot. divider (prepared in July) Transpose

??? whether should present compartmental model as such check over Ojai slides.

(4) (Fig. 5) Intracell, Extracell & P.D. comput. illustration.

(5) Four level data (can show that periods I & II approx O.K. but what about period III - granule)

(6) (Fig. 10) Granule Intracell, Extracell & P.D. comput. illust.

(7) Superposition

? How much to say about EM evidence of new pathway.

(8) Golgi diagrams could be used as basis for discussion.

(9) ? Tom's serial sections reconstruction, or pair of synapses?

(10) Reserve slide of 4 theoretical series (two active & two passive)

8/4/65

Be prepared to justify 7 and 7/2 lengths and also to say something about safety factor. How much of this to incorporate in slide.

8/9/65 Tom Reese got letter of acceptance from Dr. Windle, apparently no changes required.

Also Tokyo trip authorization, passport, reservations etc all in order by end of previous week. Also got letter from Masao Ito inviting me to preCongress symposium on Cerebellum

Also refereeing job done for Dirk FitzHugh & one coming up Fuortes

8/12/65 Today have a complete set of slides & prints thereof, except for those needed from Tom Reese.

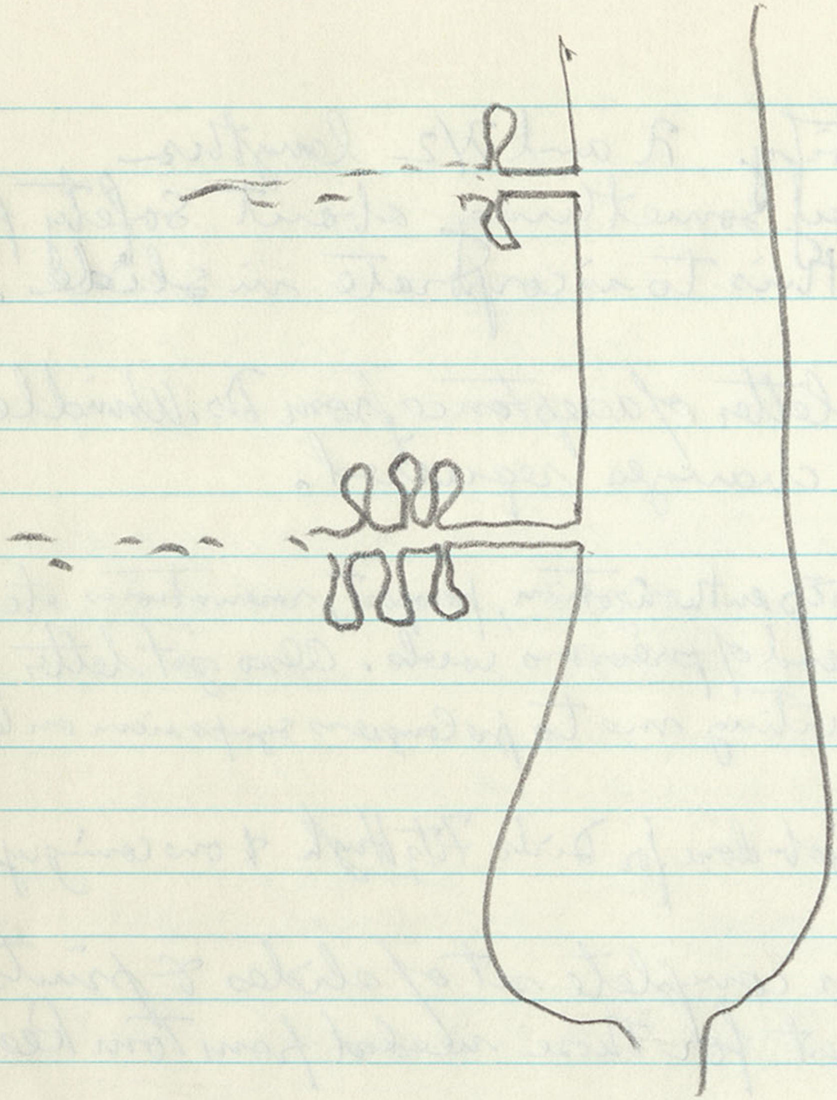
8/27/65 Slides all ready, rough outline ready. Letters written

Today concentrate on sending Gordon a set of figs. 5–11 and the rough typing

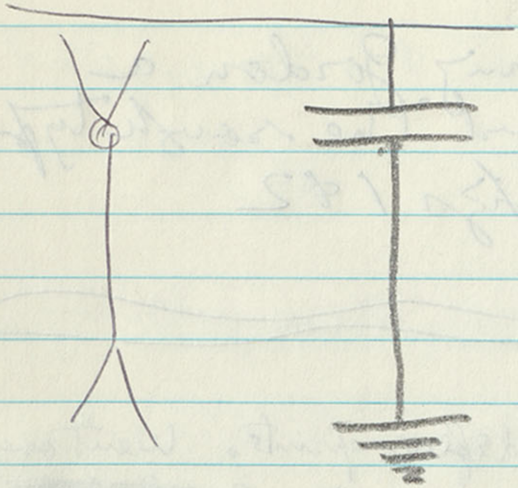
He is to take care of figs 1 & 2

9/20/65 back from Tokyo. Mailed a few reprints. Went over notes of trip & planning to mail more reprints. ~~[illegible]~~

Thinking about foreign travel report. Prepared forms for travel reimbursement. Phil Nelson called & wanted to send over Tom Smith manuscript & anomalous rectification.



Per says that
Eccles says this is like a condenser
with ground side at the depth
& not at the surface



My inspection of the records
suggests slight leak around,
but not much, and actually,
neither end seems to be
at ground.

9/24/65

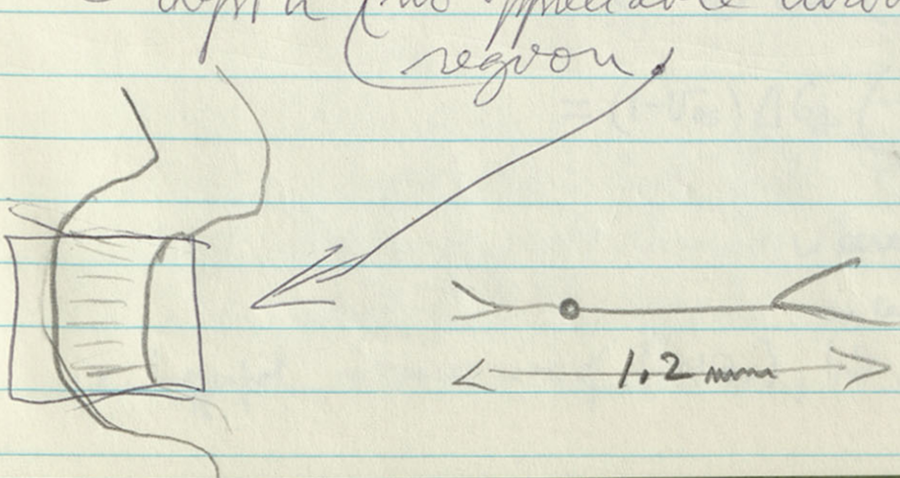
Per Andersen visited. With physicist Torstein Rudjord
Lab. of Neurophysiol.
Karl Johans gate 47
Oslo

He has built a neuron model of copper & simulates electrotonus with heat conduction & radiation. I urged him to double-check scaling of λ.

It seems this one is in geometric proportion to original, but in copper

He feels in hippocampus, it is important to distinguish between the smooth dendritic trunks of large diameter & the small calibre side branches which have many spines. He thinks the small side branches may get almost short circuited, but their fine stems (may have significant core resistance I emphasized) whereas trunks have little decrement.

They seem to be inclined to conclude impulse propagation along the smooth trunks. May be valid because the apparent spike does get delayed and apparently not attenuated with distance. However must be cautious because mostly extracellular. Regard ground as at the depth (no appreciable curvature in this region.



9/27 Foreign travel report completed. Dorothy retyping -
Bill Hogins sent me paper to referee.
Dan Poller phoned about ρ, newly estimated 3 to 10
and tapered dendrite electrotonus causing them
trouble. I suggested they fit my e^{-KZ}

Karl Frank, Phil Nelson & Tom Smith wish to talk about
remote synapses, etc. Refer back to pp 89 – 115
of Book 6

Also, go on to field effects in Book 6

Initial slope from a st st.

$$\boxed{\left.\frac{dv}{dt}\right|_{t=0} = (1 - V_{os})\frac{\Delta G_E}{C_m}}$$

for J & Ψ constant

also, if initially J & E are zero $V_{os} = \Psi$ and $1 - V_{os} = 1 - \Psi$

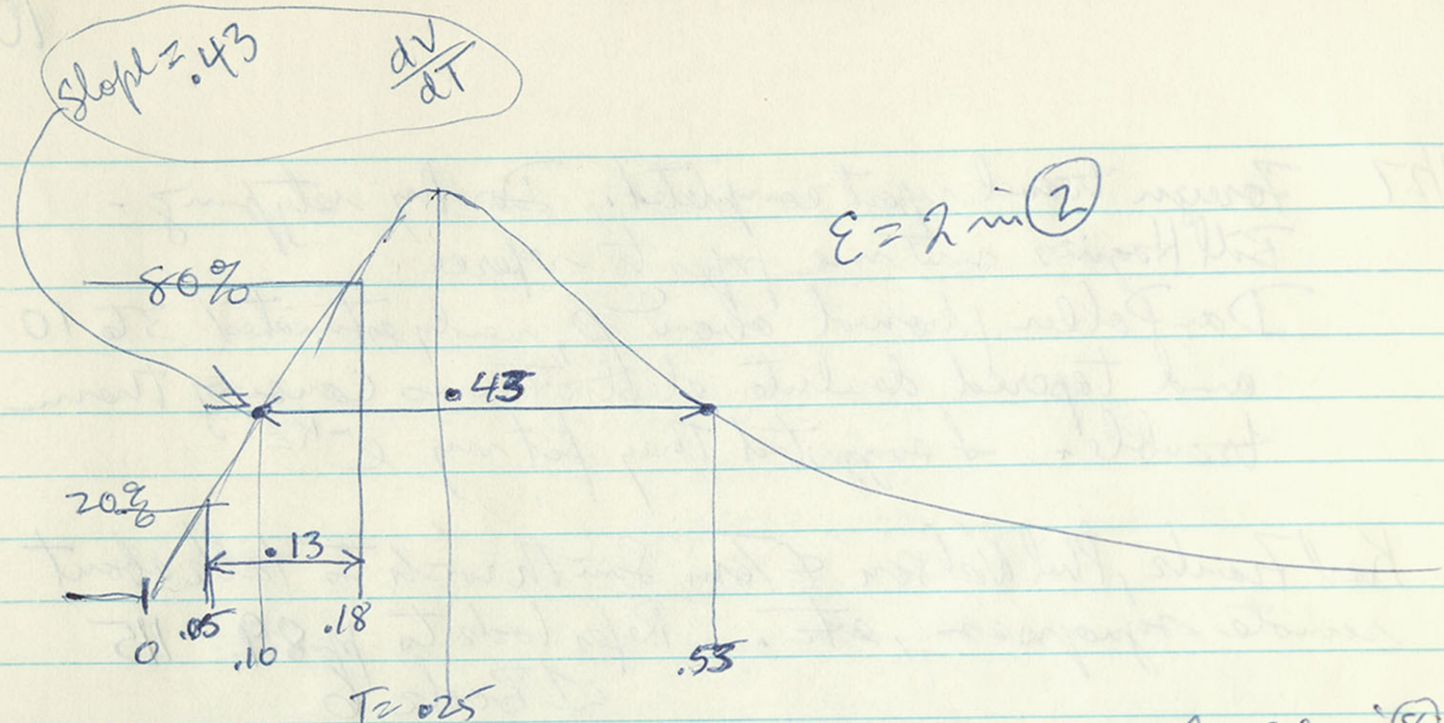
also, from p. 90 of book 6, locally induced epsp peak $= \frac{\tau \mathring{v}_0}{\mu\tau}\left(1 - e^{-\mu\Delta t}\right)$

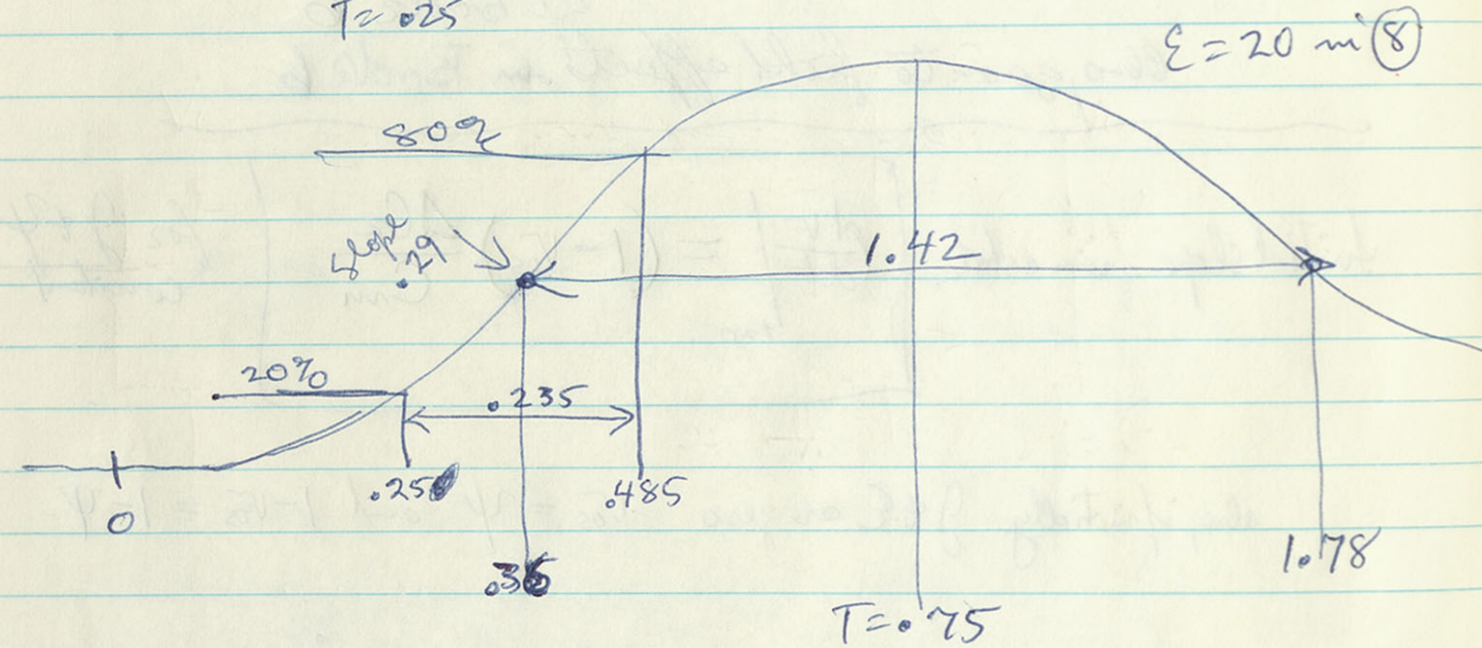
$$= (1 - V_{os})\frac{\Delta G_E}{C_m}\left(\frac{1 - e^{-\mu\Delta t}}{\mu}\right)$$

$$= (1 - V_{os})\,\Delta G_E\left(\frac{1 - e^{-\mu\Delta t}}{G_r + G_E}\right)$$

where μ is increased by G_r
in case of anomalous rect.

i.e. hyperpol. increases mag of $(1 - V_{os})$, but decreases mag of





$$\frac{.235}{.13} = 1.8$$

$$\frac{1.42}{.43} = 3.3$$

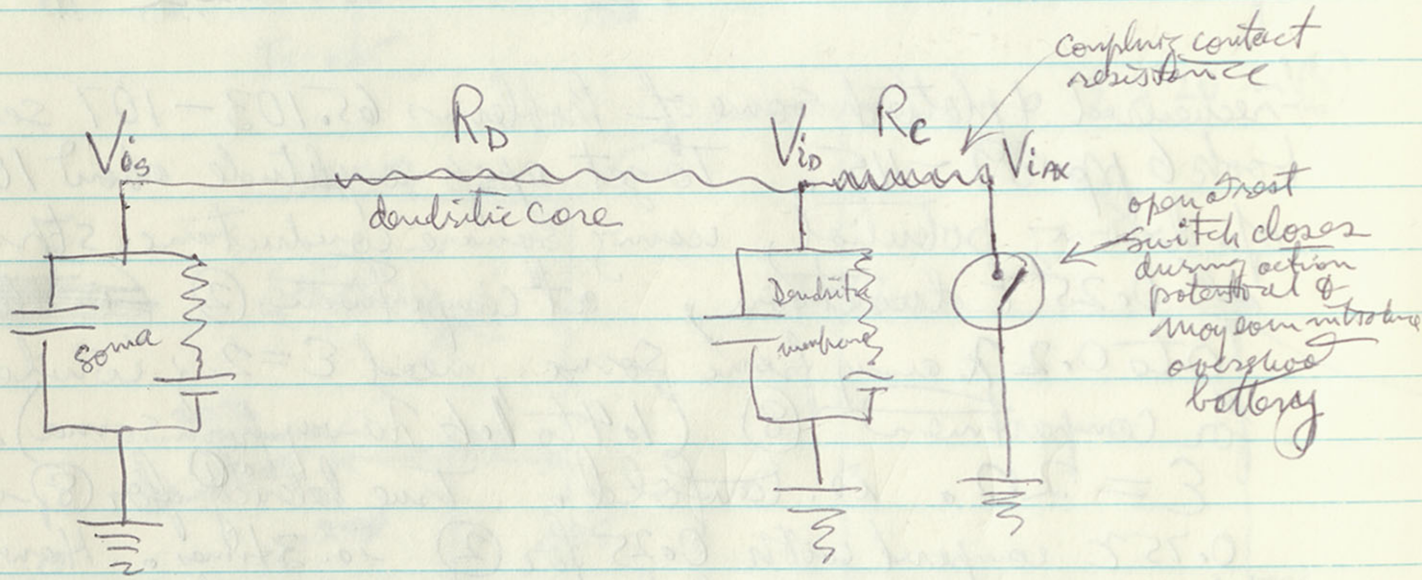
but this criterion depends upon square ε & absence of late ε.

9/29 preparing memo for T.G. Smith, R. Waerker, K. Frank & P.G. Nelson.

Their revised manuscript seems to be slanted as though Eccles chemical synapse at soma is only serious suggestion to aim at. But actually, in 1960, on p.521, I specifically compared epsp & ipsp and suggested that "ipsp is initiated mainly near the soma" and "that a significant amount of epsp initiation probably takes place in the dendrites as well as the soma".

I rechecked & plotted some of Problems 65.103 – 107 see book 6 pp 89 – 115. To get epsp amplitude about 10% of driving potential, using square conductance steps of 0.25 τ duration, at compartment (2) ~~(0.2 to 0.4)~~ 0 to 0.2 λ away from soma, need $\varepsilon = 2$, while for compartment (8) (1.4 to 1.6 λ away from soma) need $\varepsilon = 20$. i.e. tenfold. True latency at (1) for (8) is 0.75 τ compared with 0.25 for (2) i.e. 3 times. However, have problem of initial lag. Try to handle this by looking at maximum rate of rise, or a time of rise from 20% to 80% of peak where (2) gives 0.13 τ and (8) gives 0.235 τ, a factor of about 1.8

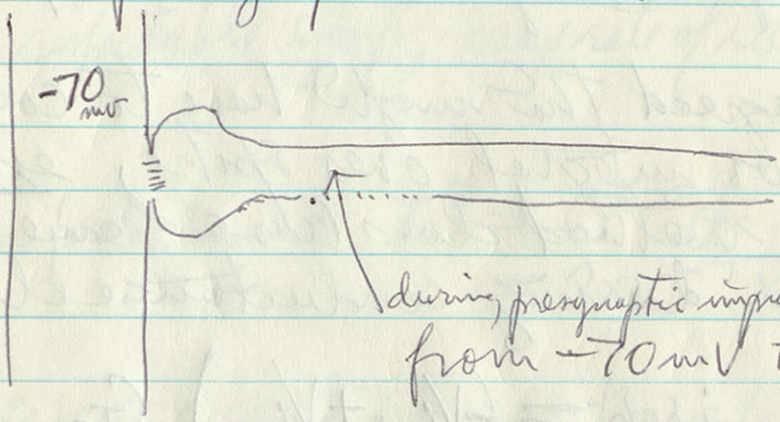
* However, this may be the time to get away from square conductance changes. Also, for longer lasting conductance changes, the distinction also gets blurred. Idea would be to generate , and make the appropriate λ_s depend upon this


coupling contact resistance
R_D
V_{iS}
V_{iD}
R_C
V_{iAx}
dendritic core
soma
Dendrite
membrane
open circuit switch closes during action potential & may som introduce overshoot battery

9/29

The concept of "constant current source" is not really fully appropriate. I wrote Jerry Lettvin (March 1962) to point out that the evidence leading to this suggestion could be accounted for by dendritic synapses.

What is "injection" of current? How? Not by the electrical synapse. My electrical synapse is not independent of the postsynaptic membrane potential. Also, it does not operate without a conductance change effective in the postsynaptic element.



during presynaptic impulse, this goes transiently from -70 mV to peak (? +30 mV) overshoot

The driving potential for current "injected" is the difference between V_i of postsynaptic element and V_i of presynaptic element.

When injected currents are put in parallel, the coupling conductances are also put in parallel.

When this was discussed with K. Frank & Phil Nelson, Phil placed great emphasis upon the greater amplitude of the presynaptic action potential, ~~both~~ to get perhaps as much as a factor 2'
corresp to my 1.5 at bottom of p. 16.

However, K agreed that might have to consider average, or integral over spike, except that Tom's method does have some time resolution during conductance change.

Crux is this $\quad ipsp = (-Vi_{post} + Vi_{pre})\, G_c$

where Vi_{post} changes only slightly, but can be altered by applied current

Vi_{pre} is det. by presynaptic spike
or is simply Ve for conventional case.

G_c is a function of time

Thus $I(t) = \Delta V(t) * G(t)$

For a given epsp, we can take $I(t)$ as given. Therefore, for each time

$$(V_e - Vi_{post})\, G_\epsilon = (Vi_{pre} - Vi_{post})\, G_c$$

postsynaptic conductance change $\qquad$ electrical synapse

9/29

Compare Electrical & Standard Synapses at Soma

Suppose $R_N = 10^6$ ohm for large neuron

And naive $\tau_N^* = 2$ msec $= 2\times10^{-3}$ sec

Then naive $C_N^* = \frac{\tau_N^*}{R_N} = \frac{2\times10^{-3}}{10^6} = 2\times10^{-9}$ farad

For a respectable epsp, max rate of rise $\simeq 10$ mv/msec
$= 10$ volt/sec

$\therefore$ peak current, $I^* = C^* \frac{dV}{dt}$
$= 2\times10^{-9} \times 10 = 2\times10^{-8}$ amperes

If this peak current is driven through the coupling resistance by 100mV, driving potential, we can estimate the resultant parallel resistance of these coupling resistances 60 mV

$$I^* = 10^{-1}\text{ volt} \times \Sigma G_c$$

$$\Sigma G_c = \frac{2\times10^{-8}}{6\times10^{-2}} = .33\times10^{-6}$$

$\therefore$ $\Sigma G_c = 2\times10^{-7}$ mho

compared with $G_N = 10^{-6}$ mho

Thus, opening switch to expose ΣG_c should give a 20% increase in conductance.

Now for standard, Driving pot. might be only 60 mV

Then get $\Sigma G_c \simeq 3\times10^{-7}$ mho, or 30% increase in conductance

9/29

* * The final upshot seems to be that Tom is incorrect in believing that electrical case produces significantly less apparent conductance change, or that it is independent of postsynaptic membrane potential. These points are true only for his hypothetical "constant current source"

It seems likely that somatic epsp should have been detected for either chemical or electrical model. Thus, expts seem to show that dendritic loci must be used, except for that late component that sometimes turns over & sometimes shows a conductance change.

Furthermore, Phil points out that original motivation for the const. current source was to explain epsp that did not increase with hyperpol.ⁿ — but now they have this ~~[illegible]~~ explained by anomolous rect. & electrical synapse does not explain it.

K. said that not entirely happy at having const. epsp amplitude result from balance between increased driving pot. & decreased membrane resistance. He & I apparently independently thought of possibility of limited charge transfer ; ~~I~~ I thought in terms of fixed quota of quantal packets available instead of anomolous rect. Also must wonder whether anomolous rect. could reduce detectability of conductance change.

* Asked Phil on phone about this! He agreed for amplitude, but early slope might not be affected.

$$\int_0^\infty q_{io} e^{-\lambda_{ji}t}\,dt = \frac{q_{io}}{\lambda_{ji}}\left[-e^{-\lambda_{ji}t}\right]_0^\infty = \frac{q_{io}}{\lambda_{ji}}$$

$$\int_0^\infty q_{io}\left(\frac{\lambda_{ji}}{\lambda_{ji}-\lambda_{oj}}\right)\left(e^{-\lambda_{oj}t}-e^{-\lambda_{ji}t}\right)dt$$

$$= q_{io}\left\{\left[-\frac{(\lambda_{ji}/\lambda_{oj})e^{-\lambda_{oj}t}}{\lambda_{ji}-\lambda_{oj}}\right]_0^\infty - \left[\frac{-e^{-\lambda_{ji}t}}{\lambda_{ji}-\lambda_{oj}}\right]_0^\infty\right\}$$

$$= \frac{q_{io}}{\lambda_{oj}}\left\{\frac{+\lambda_{ji}-\lambda_{oj}}{\lambda_{ji}-\lambda_{oi}}\right\} = \frac{q_{io}}{\lambda_{oj}}$$

Check solution $\frac{dq_j}{dt} = \left(\frac{q_{io}\lambda_{ji}}{\lambda_{ji}-\lambda_{oj}}\right)\left(-\lambda_{oj}e^{-\lambda_{oj}t} + (\lambda_{ji})e^{-\lambda_{ji}t}\right)$

$$= \frac{\lambda_{ji}q_{io}}{\lambda_{ji}-\lambda_{oj}}\left(-\lambda_{oj}e^{-\lambda_{oj}t} + \lambda_{oj}e^{-\lambda_{ji}t} + (\lambda_{ji}-\lambda_{oj})e^{-\lambda_{ji}t}\right)$$

$$= -\lambda_{oj}q_j + \lambda_{ji}q_i$$ Q.E.D.

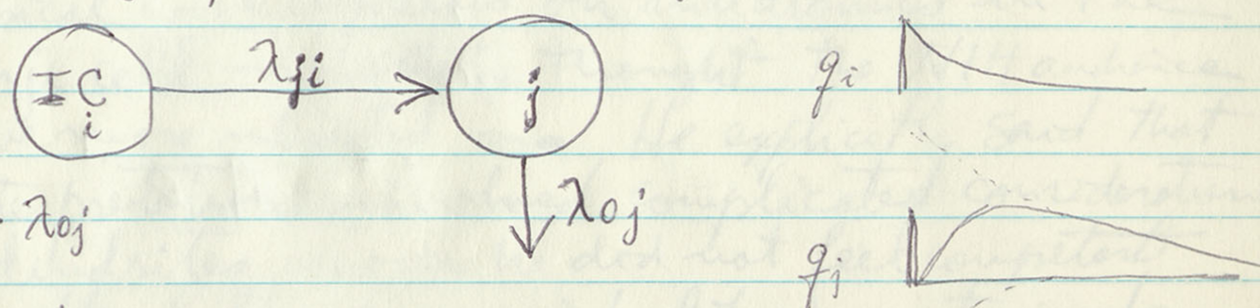
Peak occurs when $\lambda_{oj}e^{-\lambda_{oj}t^*} = \lambda_{ji}e^{-\lambda_{ji}t^*}$

$$\frac{\lambda_{ji}}{\lambda_{oj}} = e^{(\lambda_{ji}-\lambda_{oj})t^*}$$

$$\ln\left(\frac{\lambda_{ji}}{\lambda_{oj}}\right) = (\lambda_{ji}-\lambda_{oi})t^* \quad \therefore \quad \boxed{t^* = \frac{\ln(\lambda_{ji}/\lambda_{oj})}{\lambda_{ji}-\lambda_{oj}}}$$

9/30 Transient G

Plan to do future computations with $\mathcal{E}$ not square with time changes, but rather made transient by making appropriate λ dependent upon dummy compartment having exponential rise & fall



want $\lambda_{ji} > \lambda_{oj}$

$$\frac{dq_j}{dt} = \lambda_{ji} q_i - \lambda_{oj} q_j$$

$$q_i = q_{io} e^{-\lambda_{ji} t}$$

$$\therefore \frac{dq_j}{dt} = \lambda_{ji} \left(q_{io} e^{-\lambda_{ji} t} \right) - \lambda_{oj} q_j$$

Assume $q_j(t=0) = 0$

Then Laplace transformation gives, using caps for transformed variables

$$S Q_j = \frac{\lambda_{ji} q_{io}}{S + \lambda_{ji}} - \lambda_{oj} Q_j$$

$$Q_j = (q_{io}) \frac{\lambda_{ji}}{(S + \lambda_{ji})(S + \lambda_{oj})}$$

$$q_j = \left[q_{io} \right] \left(\frac{\lambda_{ji}}{\lambda_{ji} - \lambda_{oj}} \right) \left(e^{-\lambda_{oj} t} - e^{-\lambda_{ji} t} \right)$$

9/30/65

Eccles gave a lecture in Wilson Hall, although the announced title was "Ideas on the way in which the anterior lobe of the cerebellum processes the information coming to it from limb receptors" K. Frank announced that he had changed the title. New paper more biophysical with emphasis on antidromics in the Purkinje cell — which he thought the NIH audience would be more interested in. He explicitly said that the interpretations involved complicated considerations of the dendrites which he did not feel competent to handle fully & would like me to work out. In effect, he was taking credit for shunting the problem to me & was trying to provoke me into interpretations. At no time did he actually account for the extracellular potentials. He did point out that symmetrically placed off axis dendrites would tend to balance each other, which Llinas also told me — but they have a vague idea that they are better off with dendrites in the plane (Purkinje peculiarity) which I don't see as valid.

He never said what the extracellular spike is a measure of. I asked if he thought it measured membrane current density. He said no. I said he had left it implicit — he agreed & did not explain.

He has discovered that after pos. could be due to soma membrane repolarization. I did this in 61 & Frank & Nelson have published.

He thinks he has evidence for instantaneous invasion of dendrites out about 2/3 of the way. The argument is sloppy.

Mossy fiber E to Purkinje is dist over prox & dist dendrites &

If $b = a$, then $B = aA_0 t e^{-at}$

$$\frac{dB}{dt} = aA_0 e^{-at} - a^2 A_0 t e^{-at}$$
$$= aA - aB$$

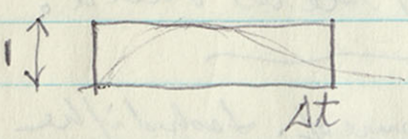
$\frac{dB}{dt} = 0$ for $t^* = \frac{1}{a}$

and for this t, we have $B^* = A_0 e^{-1}$

also $\int_0^\infty B\,dt = aA_0 \int_0^\infty t e^{-at}\,dt = aA_0 \left[\frac{e^{-at}}{a^2}(-at-1)\right]_0^\infty$
$$= \frac{A_0}{a}$$

$\therefore$ Area under B curve $= \frac{A_0}{a} = e * (B^* \cdot t^*)$

To put this another way, if want area equal to 1 unit for Δt



, choose $B^* = 1$, or $A_0 = e$
and choose ~~a~~ $t^* = \frac{\Delta t}{e}$, or $a = \frac{e}{\Delta t}$

Could Choose $\boxed{A_0 = e \text{ and } a = \frac{e}{\Delta t}}$

Then area under curve $= \Delta t$
peak amplitude $= 1$

But there is no need to have peak amplitude $= 1$. Go to page 25 + 26

9/30/65

yields an observable intracellular epsp. The parallel fiber E input is more confined to dendritic periphery & seems to produce less epsp at soma.

Interesting that small spontaneous epsp disappear during large ipsp. This is presumably the g conductance effect.

Recap from p. 20 $\quad A \xrightarrow{a} B \xrightarrow{b} \quad a > b$

$$\frac{dA}{dt} = -aA \qquad \frac{dB}{dt} = aA - bB$$

$$A = A_0 e^{-at} \qquad B = \frac{aA_0}{a-b}\left(e^{-bt} - e^{-at}\right)$$

$$\frac{dB}{dt} = \frac{aA_0}{a-b}\left(-be^{-bt} + ae^{-at}\right)$$

for $\frac{dB}{dt} = 0$, $t = t^* = \frac{\ln(a/b)}{a-b}$

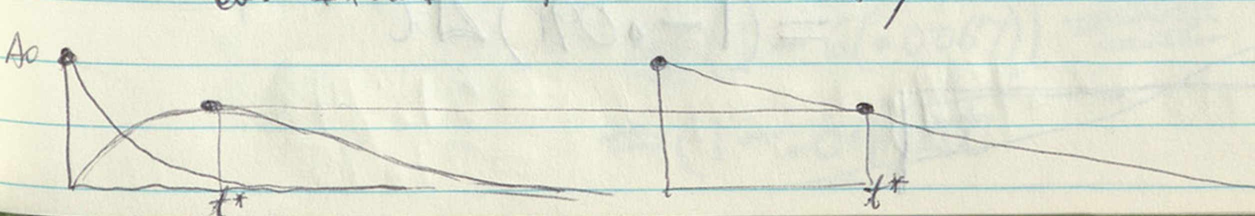
$$B^* = \frac{A_0}{a-b}\left((a-b)e^{-bt^*} + \underbrace{be^{-bt^*} - ae^{-at^*}}_{\overset{!!!}{0}}\right)$$

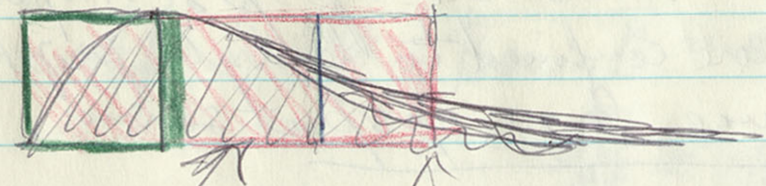
$$= \boxed{A_0 e^{-bt^*}}$$

as though initial amount A_0 decayed with rate b

also, area under B curve equals A_0/b

while that " A " " A_0/a





area under curve = e times area of small rectangle = area of large red rectangle

amplitude at) is approx 1/2 peak
area of tail is about 1/4 of that under curve

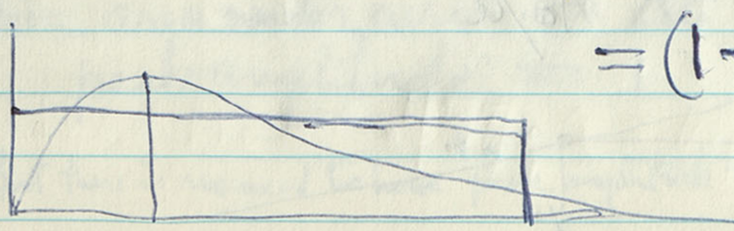
If $A_0 = 4$ and $a = \frac{4}{\Delta t} = \frac{1}{t^*}$ or $t^* = \frac{\Delta t}{4}$

Then peak $= \frac{4}{2.718} = 1.475$

and area up to them Δt becomes $\frac{A_0}{a}\left[e^{-4}(-4-1)+1\right]$

$= (1 - 5(.01832))\Delta t$

$= (1 - .091)\Delta t$



10/1/65

following p.23, it ap of interest to examine amplitude of B & area under B up to at $t = \Delta t = et^* = \frac{e}{a}$

$$\boxed{\begin{array}{l} A_0 = e \\ a = \frac{e}{\Delta t} \end{array}}$$

at $t = \frac{e}{a}$ $\quad B = eA_0 e^{-\cancel{at}} = A_0 e^{1-e} = A_0 e^{-1.718} \simeq 0.18 A_0$

compared with $B^* = A_0 e^{-1} = 0.368 A_0$

in otherwords, down to half of peak

Also $\displaystyle\int_0^{et^*} B\,dt = \frac{A_0}{a}\left[\cancel{A_0} e^{-e}(-e-1) - (-1)\right]$

$et^* = \frac{e}{a}$ $\quad = \cancel{\frac{A_0}{a}}\left[(.066)(-3.72) + 1\right]\Delta t$

$= \cancel{\frac{A_0}{a}}\left[1 - .245\right]\Delta t$

or about 3/4 of area

If want less tail can alternatively set, for example

$A_0 = 5$, then if $\frac{A_0}{a} = \Delta t$, get $a = \frac{A_0}{\Delta t} = \frac{5}{\Delta t}$

then peak $= A_0 e^{-1} = \frac{5}{2.718} = 1.84$

and area up to Δt becomes $\frac{A_0}{a}\left[e^{-5}(-5-1) + 1\right]$ $\cancel{\frac{A_0}{a}}$

$= \cancel{\frac{A_0}{a}}(1 - 6(.0067))$

$= (1 - .04)\Delta t$

26

If $B^* = 2$, and fullarea under $B = \Delta t$,

Then, because $\Delta t = e B^* t^* = 2e t^*$

it follows that $t^* = \frac{\Delta t}{2e} = \frac{\Delta t}{5.44}$

or $a = \frac{5.44}{\Delta t}$

and that $A_0 = e B^* = 2 * e = 5.44$

at Δt, factor $= \left[e^{-5.44}(-5.44-1) + 1\right]$

$= 1 - 4.44(.00434)$

$= 1 - .01925$

i.e. approx 2% of area is in tail
98% is during Δt

peak of 2 occurs at $0.184\,\Delta t$

$= 0.046$ for $\Delta t = 0.25$

suppose use T scale, and $\Delta T = 0.25$

Then $A_0 = 5.437$; $a = \mu_{ij} = \mu_{0j} = 21.748$
$= 21.75$

10/1/65

Upshot of previous pages is if set $b = a$, then have $B = aA_0 t e^{-at}$ $t^* = \frac{1}{a}$

where for area under curve to equal Δt

we choose $\frac{A_0}{a} = \Delta t$ such as following examples

A_0	a	t^*	B^*	area of tail beyond Δt
2.718	$\frac{2.718}{\Delta t}$	$\frac{\Delta t}{2.718}$	1	$0.245\,\Delta t$
4	$\frac{4}{\Delta t}$	$\frac{\Delta t}{4}$	1.475	$0.091\,\Delta t$
5	$\frac{5}{\Delta t}$	$\frac{\Delta t}{5}$	1.84	$0.04\,\Delta t$
5.44	$\frac{5.44}{\Delta t}$	$\frac{\Delta t}{5.44}$	2.0	$0.019\,\Delta t$

If want to avoid tail completely, could use Λ with peak obviously twice average height, could even shift Λ off center.

Probably should try both.

more precisely 5.4366

for $A_0 = 2.718$ & $\Delta t = .25$, $a = 10.872$

$t^* = \frac{1}{a} = .092$

65.109 got book 10/7/65

prepare from 65.106 See p.

#1	65.109	10.5.65	
#2	" 9		
1st pink card	6.		
2nd " "	6.	12 .3	
3rd	8.	—	
4th	8.	.3	
Kappa Cards	6	.4	
	8	.4	
	10	.25	
New K cards	10	11	
	10	12	
Time Change Cards	6	12	30.
	0	12	-30
	0	6	31.
	0	6	1.
	8	12	60.
	0	12	-60.
	0	8	61.
	0	8	1.

10/5/65

Set up new 65.500 Series for epsp (next page)
with transient conductance change!
Later plan to have only 5 compartments of larger ΔZ,
but first, plan to match previous 65.100 series
as closely as possible.

Also, do J very soon

Also, set up 65.108 (refer back to pp. 89–105 of book 6

Try $\varepsilon = 30$ in 10 } 65.108
$\varepsilon = 40$ in 10

$\varepsilon = 30$ in 6 } 65.109
$\varepsilon = 60$ in 8

got back
10/7/65
see p. 40

Took old 65.107 and change to 65.108 at 20 SAAM22 at 28 10.5.65

#2 65.108

1st pink card, change	4. to	10. (345)	& duplicate
2nd		10.	.3 at 12 & duplicate
Kappa card	10 (45)	.25 (12)	
New Z cards	10 (45)	11 (910)	
	10	12	
Time change cards	10	12	30. (26)
	0	12	-30.
	0	10	31.
	0	10	1. duplicate
	10	12	40.
	0	12	-40.
	0	10	41.
	0	10	1.

3
30
30
10
20
4x5
93
112
30
20
235

~~3x55 = 165~~
~~3x~~

2x55 = 110
2x 30 = 60
4x10 = 40
15
225

really 11x14

12x15

use 11 as E for first T.C.
12 as E for second T.C.

During first time period, let 13 feed 14 & set 15 = 1.0
2nd " " 13 feed 15 & set 14 = 1.0

Instead of manipulating out λ of perturbed cpt.
use an additional loss into cpt. 16

Initial Condition Changes

13	5.437
11	0.
12	1.
14	0.
15	0.

26 7
26 10
26 11

Note heirarchy within each time change. (1) Initial values of q & λ set
(2) λ dependence relations satisfied
(3) finally q dependence factor introduced.

10/5/65 Got back 10/7/65

See p. 38

65.500 Series

	13	20	28	40		72	80
Card #1	65.500	SAAM 22	10.5.65	RALL	TRANSIENT G	65.5	1
2	[2] 65.501	[19] 1 [20] 6				65.5	2
3			[31] .01	[41] .98	[61] .98	65.5	3
4	[4] 3	[10] OPTIONS				65.5	4

Data Cards first three cards as before setting opt. 1 at -.1, +.35 and 0.

4th data card [2] 200. [12] .05 [42] ~~50.~~30. duplicate twice

5th pink [2] 2.

~~6th yellow like 4th~~ ~~14.~~

~~7th 126. 14. .15~~ also with 200. .1 10.

~~1.~~

~~Stet 200. .05 55. duplicate twice~~

~~pink 8.~~

~~200. .05 55.~~

~~14. .15.~~

~~26. 200. .1 10.~~

Initial Conditions ~~11 & 12 as before~~ set 11 = 1.
12 = 0.

[4] 13 [12] 5.437

~~[4] 15~~ [12]

Kappa 10 .05 .25
.1

lambdas to add [11 13, 14, 15]

[9]	[10]	[12]		[58]	[59]
8	14	21.75			
14	13	yes 21.75	~~21.75~~ 21.75	1	1
15	13	yes	21.75	1	2

Perturbed λ

	[10]	[12]	[58 59]
~~pink 0~~	~~2~~	~~2~~	~~14~~
16	2	2.	14
2	12	2.	14
16	12	-2.	14
16	8	20.	15
8	12	20	15
0	12	-20.	15

			58 59
16	5	10.	14
16	10	10.	14
5	12	10.	14
10	12	10.	14
0	12	-20.	14

26 ——————————— 3

Sigmas

		12
17	10	1.
17	5	1.

26 4

Old dependent relations.

delete 56 & 65

26 ——— [redacted] 13 set to 5.437 5

26 6

20 14 21.75

7 14 13 21.75

10/5/65

over-ran 250 data points by one. See p. 37

65.600 series

Two short 5 compartment chains $\lambda_{ij} = 6.25$

one ~~[illegible]~~ time change to ~~start~~ transient $\mathcal{E}$ at $T = 1.0$

Save 11 for inhibition
12 for $\mathcal{E}$
13 for source to 14 — 17 for summer.
14 for transient
16 for extra sink
15 for source of applied current

#1 65.600 SAAM 22 10.5.65 Roll TWO CHAIN TRASIENT $\mathcal{E}$

2 ~~15~~ 17 cpts — 65.6 1 otc

~~.45~~ & zero

Data cards three cards for 1 as before

200.	.1	10.	
1.	1.05	~~2~~	
200.	.05	~~20. 19~~ 34.	~~cpts to [illegible]~~
~~1.~~	~~1.15~~		

Same for 5., 6., 10. and 17. (=.45 & zero; -.45 & zero) — ~~5×45~~ OK.

Initial conditions set 11 at -.1
12 at 1.0
13 at 5.437 → only at 1st T C
15 at 1.0

Kappas { cpts 2,3 & 7,8 at 0.5 — 14 has .05
cpts 4,5, 9,10 at 0.25 — 17 has 5

lambdas $\lambda_{12} = 6.25$ all other λ_{ij} depend except delete λ_{56} & λ_{65} — all $\lambda_{0j} = 1$

λ_0 14 = ~~[illegible]~~ 21.75 0
λ_{14} 13 = 21.75 0 after T.C.
λ_1 15 = 1.
λ_6 15 = -1.
~~λ_0 15 = 2.~~

10/5/65

Having set up these problems and new series. Try to return to idea of writing in the morning & doing odd correspondence and chores in the afternoon. As of now, chores are

Note to Gordon — collaboration memo to Research Grants already sent.
Mail reprints to Japan, F.O. Schmitt, Wepman, ? others.
Write note to Katz
Abert, Brookhart J Neurophysiol
Write Mannen, Iwase, Kitasato, ? Ito

10/6/65 Began to work on Cortical Potential Field Theory paper, going over old notes.

Concentrate first on

Cortical Potential Fields: Theory for Synchronous Activity in Layers of Oriented Neurons.

Then pick up

Extracellular Potential Field for Single Neuron with Radially Symmetric Dendritic Arborization

? Write letter of inquiry or telephone — J. Theoret. Biol.
— J. Neurophysiol.
delay time — Exp. Neurol.
willingness to take straight theory — new Brain Research (Abert)
EEG & Clin Neurophysiol
J. Physiol.

for more precision could make $T_{max} = 2.2$

with smallest $\Delta T = 0.02$

because $(110)(.02) = 2.2$

and double amplitude scale. ✓ did for 502

for 502 Changed scales

also changed I.C. in 13 from 5.437 to 2.718

and " λ_{014}, λ_{015}, $\lambda_{14,13}$, $\lambda_{15,13}$ all

from 21.75 to 10.87

This makes peak = 1 at $T = 0.37 \Delta T$

$= 0.09$ for $\Delta T = .25$

see pp 26-28

for 602 also changed $5.437 \xrightarrow{\text{to}} 2.718$

$21.75 \longrightarrow 10.87$

Also reduced data points

& corrected erroneous data values.

10/7/65

Got back 65.108, 65.109 } Successful
65.501 } present here now
65.601 — did not run because 250 data point limit was exceeded by one.

65.501 Transient G $\boxed{\text{This worked}}$
with I.C. in 13 set at 5.437
and $\lambda_{014} = \lambda_{015} = 21.75 = 4(5.437)$
$\lambda_{14,13} = \lambda_{15,13} = 21.75$

see p. 27&28

Thus, cpt 14 should have had a peak value of 2.0 at T = 0.046
and should have been 98% complete at T = 0.25

In 2, $\mathcal{E} = 2 * Q_{14}$ which peaked at 4 but average 2 over $\Delta T = .25$

This gave in cpt 1 peak at T = 0.2 compared with 0.25 for square 65.106

also, steepest slope was +.94 at T ≃ .07 compared with 0.48 T ≃ .10

But need finer resolution of data points for precision.
falling slope @ halfway = −.11 agrees with 65.106

In 8, $\mathcal{E} = 20 \times Q_{15}$ which peaked at 40 but averaged 20

This gave in Cpt. 1 approx same peak time & slopes
T = 0.75 +.27 −.05

∴ revise, see left

65.109 Square G $\varepsilon = 30$ in (6)
$\varepsilon = 60$ in (8)

$\varepsilon = 30$ in (6)

peak in (6) was 0.651 at T = 0.25

peak in (1) was 0.197 at T = 0.50

close

max slope ≃ 0.7 at T = 0.25

falling slope at half max ≃ −0.1 at T = 1.35

$\varepsilon = 60$ in (8)

peak in (8) was 0.827 at T = 0.25

peak in (1) was 0.161 at T = 0.75

max slope ≃ 0.43 at T = 0.35

falling slope at half max ≃ −0.076 at 1.75

not so close

Decided to do new runs with better time resolution, and also use iterations to fit the desired epsp max amplitude.

See 65.150 series p. 42

10/7/65

65.108 Square G $\varepsilon = 30$ in 10
$\varepsilon = 40$ in 10

$\varepsilon = 30$ in 10

peak in 10 was 0.778 at $T = 0.25$

peak in 1 was 0.085 at $T = 0.9$

max slope approx +0.2 at $T = .45$

falling slope at half max ≈ −0.04 at $T = 1.90$

$\varepsilon = 40$ in 10

approaching St. St. value

peak in 10 was 0.828 at $T = 0.25$

peak in 1 0.0921 at $T = 0.9$

max slope approx +0.22 at $T = 0.45$

falling slope −0.043 at $T = 1.90$

almost 0.10
incorporated in Chart

amplitude of epsp to be fitted

perturbed cpt.

65.~~1524~~
424

Same time + data card setup as 65.1522

But special weighted data card here

4	12	27	~~42~~
1.	.35	.20	~~15.~~

				60
$\lambda_{0,13}$	10.1	10.0	11.4	
$\lambda_{0,12}$				1
$\lambda_{4,12}$				1
$\lambda_{13,4}$				1

Dependence Cards

4,5	9,10	19,20	24,25	27
0	12	0	13	-1.
4	12	0	13	+1.
13	4	0	13	+1.

ahead of this ~~need~~ control card

	42	57
100.	.01	1

10/11/65

10/8/65

amplitude of epsp

perturbed cpt.

65. ~~1522~~ 422

Square G FIT

Studied 65, 108 & 109

Since we know peak locations, it is now possible to redo this with an iteration to get peaks amplitudes almost exactly matched.

Also, can get finer detail for early slopes. Possibly change scales, as done ~~yesterday~~ on page 37 for .502

Method would be to use λ_{013} as dummy factor for adjusting

$$\left.\begin{array}{l}\lambda_{2,12}\\ \lambda_{0,12}\\ \lambda_{13,2}\end{array}\right\}$$

and G_{13} also as a similar for ~~$\lambda_{13,6}$~~ perturbed out λ

Then have dependence relations of upon λ_{013}

This was done $\boxed{\text{10/11/65 Roll Square G FIT}}$

3 iterations

		initial 12	min 27	max 42	60
65.1522	$\lambda_{0,13}$	4.1	4.0	4.5	
	$\lambda_{0,12}$				1
	$\lambda_{2,12}$				1
	$\lambda_{13,2}$				1

Dependence Cards	4,5	9,10	19,20	24,25	27
	0	12	0	13	-1.
	2	12	0	13	+1.
	13	2	0	13	+1.

Weighted Data Card	4	12	27	42	
	1.	.25	.20	15.	weight

$\pi^2 = 9.8696 \simeq 9.87$

$4\pi^2 = 39.48$

$9\pi^2 = 88.83$

$16\pi^2 = 157.9$

L=1	L=2	L=3
$\alpha_1^2 = 1 + 9.87 = 10.87$	$1 + 2.47 = 3.47$	$1 + 1.097 = 2.097$
$\alpha_2^2 = 1 + 39.48 = 40.48$	$1 + 9.87 = 10.87$	$1 + 4.38 = 5.39$
$\alpha_3^2 = 1 + 88.83 = 89.8$	$1 + 22.2 = 23.2$	$1 + 9.88 = 10.88$
$\alpha_4^2 = 1 + 157.9 = 158.9$	$1 + 39.5 = 40.5$	$1 + 17.54 = 18.54$

L=4

$1 + .62 = 1.62$

$1 + 3.47 = 4.47$

$1 + 5.56 = 6.56$

$1 + 9.87 = 10.87$

$1 + 15.42 = 16.4$

$1 + 22.2 = 23.2$

	L=1	L=2	L=3	L=4
α_0^2	1.0	1.0	1.0	1.0
α_1^2	10.9	3.47	2.10	1.62
α_2^2	40.5	10.9	5.39	4.57
α_3^2	89.8	23.2	10.9	6.56
α_4^2	159.0	40.5	18.5	10.9
5	248.0	62.6	36.6	16.4
6				23.2

Could publish this table

Might rename α_n^2, say ~~κ_n~~

or use $\tau_n = \tau_{0n}/\alpha_n^2$

Then $\alpha_n^2 = \tau_{0n}/\tau_n$

$$\tau_m = \frac{\tau_{0m}}{1 + (m\pi/z_m)^2}$$

10/12/65

Write: Note on Time Constants of Non-Uniform Decay

~~Passive Membrane~~

Passive Decay ~~of Exponents for~~ of Non-Uniform Membrane Potential

Begin from Eqs. 30-35 of N.Y. Acad. Science paper.

Set $k^2=1$, $V^*=0$, consider $V(0,T)$ & $V(Z_m,T)$

where $Z_m = B = L$ of old paper $L=\int_0^\infty \frac{dl}{\lambda}$

L=5
1.0
1.40
2.58
3.74
7.3
10.9

use L

$\alpha_n^2 T = t/\tau_m$

$$V(0,T) = \sum_0^\infty C_n e^{-\alpha_n^2 T}$$

$$V(L_m,T) = \sum_0^\infty C_n (-1)^n e^{-\alpha_n^2 T}$$

$$\alpha_n^2 = 1 + (n\pi/Z_m)^2$$

$$C_n = \frac{\int_0^{Z_m} V(Z,0)\cos\left(\frac{n\pi Z}{Z_m}\right)dZ}{\int_0^{Z_m}\cos^2\left(\frac{n\pi Z}{Z_m}\right)dZ}$$

$$C_0 = \frac{1}{Z_m}\int_0^{Z_m} V(Z,0)\,dZ$$

for $n>0$, $C_n = \frac{2}{Z_m}\int_0^{L} V(Z,0)\cos\left(\frac{n\pi Z}{Z_m}\right)dZ$

for $A/L = .05$ get $\frac{\sin 9^\circ}{\pi/2} = \frac{.1564}{1.5708} = .099567$ $\frac{\sin 36^\circ}{2\pi} = \frac{.5878}{6.2832} = .093551$

$\frac{\sin 18^\circ}{\pi} = \frac{.3090}{3.1416} = .098357$

$\frac{\sin 27^\circ}{3\pi/2} = \frac{.4540}{4.7124} = .096341$

Suppose $\frac{A}{L} = 0.1$

Then $\sin\left(\frac{\pi A}{L}\right) = \sin(18^\circ) = 0.309$

and $C_1 = \frac{2(.309)}{\pi}(V_0 - V_B) = 0.197(V_0 - V_B) \approx 0.2(V_0 - V_B)$ which is the approx formula

$C_2 = \frac{2(V_0 - V_B)}{2\pi}\sin(36^\circ) = (V_0 - V_B)\left(\frac{.588}{3.14}\right)$
$= 0.187(V_0 - V_B)$

$\frac{C_1}{V_0 - V_L}$ $\sin(18^\circ)/\pi/2 = \frac{.3090}{1.5708} = .196715$ Friden

$\frac{C_2}{V_0 - V_L}$ $\sin(36^\circ)/\pi = \frac{.5878}{3.1416} = .187102$

$\frac{C_3}{V_0 - V_L}$ $\sin(54^\circ)/(3\pi/2) = \frac{.8090}{4.7124} = .171674$

$\frac{C_4}{V_0 - V_L}$ $\sin(72^\circ)/(2\pi) = \frac{.9511}{6.2832} = .151371$

$\frac{2 \times .707}{3.1416} = \frac{1.414}{3.1416} = .45 = \frac{1}{2.22}$

If $A = \frac{L}{4}$, would get $C_1 = 2(V_0 - V_B)\frac{\sin\left(\frac{\pi}{4}\right)}{\pi} = 0.45(V_0 - V_B)$

$C_2 = $ " " $\frac{\sin \pi/2}{2\pi} = 0.318(V_0 - V_B)$

$C_3 = $ " " $\frac{\sin 3\pi/4}{3\pi} = 0.15(V_0 - V_B)$

$C_4 = 0$

$C_5 = 2(V_0 - V_B)\frac{\sin(\pi + \pi/4)}{5\pi} = -0.09(V_0 - V_B)$

$C_6 = $ " " $\frac{\sin(\pi + \pi/2)}{6\pi} = -0.106(V_0 - V_B)$

$C_7 = $ $= -0.064(V_0 - V_B)$

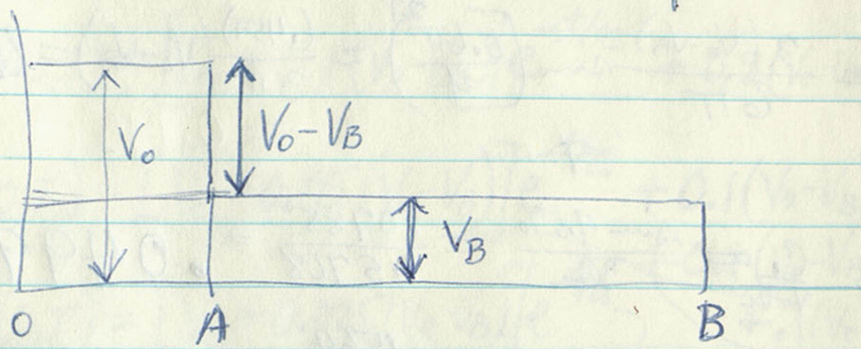
$C_8 = 0$

5 $\frac{\sin 90^\circ}{5\pi/2} = \frac{.2}{\pi/2} = .1273$

6 $\frac{\sin 108}{3\pi} = \frac{\frac{1}{3}(.9511)}{\pi}$

10/12/65

Suppose $V(Z,0) = \begin{cases} V_0 & \text{for } 0 \le Z \le A \\ V_B & \text{for } A \le Z \le B \end{cases}$



Then $C_0 = \frac{1}{L}\int_0^L V\,dz = V_B + \left(\frac{A}{L}\right)(V_0 - V_B)$

$$C_n = \frac{2}{L}\left[V_B \int_0^L \cos\left(\frac{n\pi z}{L}\right)dz + (V_0 - V_B)\int_0^A \cos\left(\frac{n\pi z}{L}\right)dz \right]$$

$$= \frac{2}{\cancel{L}}\underbrace{\left[\frac{V_B \cancel{L}}{n\pi}\sin\left(\frac{n\pi z}{L}\right)\right]_0^L}_{\equiv\, 0} + \frac{2}{\cancel{L}}\frac{(V_0 - V_B)\cancel{L}}{n\pi}\left[\sin\left(\frac{n\pi z}{L}\right)\right]_0^A$$

$$= \frac{2(V_0 - V_B)}{n\pi}\sin\left(\frac{n\pi A}{L}\right)$$

this is my value

For $n=1$, and $\frac{\pi A}{L}$ small, get $C_1 = 2(V_0 - V_B)(A/L)$

But if, for example, $A = \frac{L}{2}$, then get $C_1 = 2(V_0 - V_B)/\pi$

$2/\pi = .6366$

$-\frac{2}{3\pi} = -.2122$

$+\frac{2}{5\pi} = +.1273$

and $C_2 = 0$

$C_3 = -1$

$$C_n = (2/n\pi)(V_0 - V_B)(-1)^{(n-1)/2}$$

Step Nonuniformity

22.5°

for $L=4$

$$C_5 = \frac{2(V_0-V_B)}{5\pi}\sin\left(\frac{0.5\pi}{4}\right) = \frac{(.4)(.383)}{\pi}(V_0-V_B) = .0488(V_0-V_B)$$

27°

$$C_6 = \frac{2(V_0-V_B)}{6\pi}\sin\left(\frac{0.6\pi}{4}\right) = \frac{(.454)}{3\pi}(V_0-V_B) = 0.0482(V_0-V_B$$

$A/L = .025$ $\quad \frac{C_1}{V_0 V_2} = \frac{\sin 4.5°}{\pi/2} = \frac{.0785}{1.5708} = .049974$

2 $\quad \frac{.1564}{3.1416} = .049783$

3 $\quad \sin 13.5 \quad \frac{.2334}{4.7124} = .049528$

4 $\quad \sin 18 \quad \frac{.3090}{6.2832} = .049178$

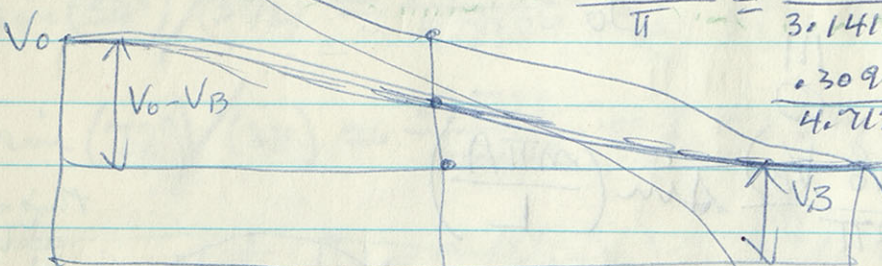
5

$A/L = .0333$ $\quad \frac{\sin 6}{\pi/2} = \frac{.1045}{1.5708} = .066526$

$\frac{\sin 12}{\pi} = \frac{.2079}{3.1416} = .066176$

$\frac{.3090}{4.7124} = .065571$

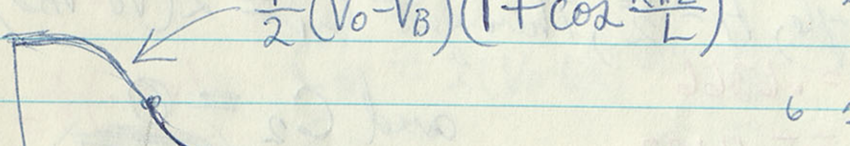
$\frac{.4067}{6.2832} = .064728$



5 $\quad \frac{\sin 22.5}{2\pi+\pi/2} = \frac{.3827}{7.8540} = .48726$

$$\frac{1}{2}(V_0-V_B)\left(1+\cos\frac{k\pi z}{L}\right)$$

6 $\quad \frac{\sin 27}{3\pi} = \frac{.4540}{9.4248} = .48170$



A

$2A = L/k$

See p. 50

10/12/65

~~Compare A/L = 0.1 with L =~~ Step Nonuniformity

Consider $A = 0.1$ & compare $L = 1, 2, 3$

for $L=1$, get $V(0,T) = \left[V_B + 0.1(V_0 - V_B)\right]e^{-t/\tau_0} + 0.2(V_0 - V_B)e^{-11t/\tau} + \dots$

for $L=2$, get $V(0,T) = \left[V_B + 0.05(V_0 - V_B)\right]e^{-t/\tau_0} + 0.1(V_0 - V_B)e^{-3.5t/\tau}$
$+ 0.1(V_0 - V_B)e^{-11t/\tau} + \dots$
$+ .1(V_0 - V_B)e^{-23t/\tau}$

for $L=4$, get $V(0,T) = \left[V_B + 0.025(V_0 - V_B)\right]e^{-t/\tau_0}$

$$
\begin{aligned}
&+0.05(V_0 - V_B)e^{-1.6t/\tau}\\
&+0.05(V_0 - V_B)e^{-4.5t/\tau}\\
&+0.05(V_0 - V_B)e^{-6.6t/\tau}\\
&+0.049(V_0 - V_B)e^{-11t/\tau}\\
&+0.049(V_0 - V_B)e^{-16.4t/\tau}\\
&+0.048(V_0 - V_B)e^{-23.2t/\tau} \quad \text{etc}
\end{aligned}
$$

is midvalue $L/2$

Consider also $V(Z,0) = \left\{ V_B + \dfrac{V_0 - V_B}{2}\left(1 + \cos\left(\dfrac{\pi Z}{L}\right)\right)\right.$

Then, orthogonality knocks out all C_n for $n > 1$

$$C_0 = V_B \qquad C_1 = \frac{2}{L}\int_0^L V \cos\left(\frac{\pi Z}{L}\right) dZ = \frac{V_0 - V_B}{2}$$

$$C_n = 0 \text{ for } n > 1$$

If $V(Z,0) = V_B$ for $2A \le Z \le B$

$V_B + \frac{1}{2}(V_0 - V_B)\left(1 + \cos\left(\frac{k\pi Z}{L}\right)\right)$ for $0 \le Z \le \frac{L}{k} = 2A$

See p. 50

page 45

Test for $L=1$, $k=5$ to compare with $A=0.1$

Then $C_1 = (V_0 - V_B)\frac{25 \sin \pi/5}{\pi(25-1)} = \cancel{\frac{0.588}{24\pi}(V_0-V_B) = .0078(V_0-V_B)}$ wrong at first

$$= \frac{25(0.588)}{24\pi}(V_0-V_B) = 0.195(V_0-V_B)$$

OK

$$C_2 = (V_0-V_B)\left(\frac{25 \sin \frac{2\pi}{5}}{2\pi(25-4)}\right) = (V_0-V_B)\left(\frac{25(.9511)}{(6.28)(21)}\right) = 0.18\,(V_0-V_B)$$

72°

~~In other words, page 45 square exaggerates higher order C_n~~

$$C_3 = (V_0-V_B)\left(\frac{25 \sin 108^\circ}{3\pi(25-9)}\right) = (V_0-V_B)\left(\frac{25(+.9511)}{3\pi(16)}\right) = 0.158\,(V_0-V_B)$$

$$C_4 = (V_0-V_B)\left(\frac{25 \sin 144^\circ}{4\pi(25-16)}\right) = (V_0-V_B)\left(\frac{25(+.588)}{4\pi(9)}\right) = +.13\,(V_0-V_B)$$

$$C_5 = \frac{1}{2k} = 0.1 \qquad n=k$$

$$C_6 = (V_0-V_B)\left(\frac{25 \sin(-360)}{6\pi(25-36)}\right) = (V_0-V_B)\left(\frac{25(-.588)}{6\pi(-11)}\right) = .071\,(V_0-V_B)$$

$$\frac{(25)(.588)}{\pi} = \frac{14.7}{\pi} = 4.68 \qquad \frac{(25)(.9511)}{\pi} = 7.58$$

See p. 72 for exponential non-uniformity

10/12/65 This is cosine non-uniformity

for $V(Z,0) = V_B + \frac{1}{2}(V_0 - V_B)\left(1 + \cos\left(\frac{k\pi Z}{L}\right)\right)$ for $0 \le Z \le \frac{L}{k}$ $= 2A$

$$C_0 = V_B + \frac{1}{2L}(V_0 - V_B)\int_0^{L/k}\left(1 + \cos\left(\frac{k\pi Z}{L}\right)\right)dZ$$

$$= V_B + (V_0 - V_B)\left\{\frac{1}{2k} + \frac{1}{2k\pi}\left[\sin\frac{k\pi Z}{L}\right]_0^{L/k}\right\}$$

$$= V_B + \frac{(V_0 - V_B)}{2k}$$

$$C_m = \left(\frac{2}{L}\right)\left(\frac{1}{2}\right)(V_0 - V_B)\int_0^{L/k}\left\{\cos\frac{k\pi Z}{L}\cos\frac{m\pi Z}{L}\,dZ + \cos\frac{m\pi Z}{L}\,dZ\right\}$$

where k may be greater than m

$$= \frac{(V_0 - V_B)}{L}\left[\frac{\sin\left(\frac{k\pi + m\pi}{L}\right)Z}{2\left(\frac{k\pi + \pi}{L}\right)} + \frac{\sin\left(\frac{k\pi - m\pi}{L}\right)Z}{2\left(\frac{k\pi - \pi}{L}\right)}\right]_0^{L/k} + \left[\frac{\sin\frac{m\pi Z}{L}}{\frac{m\pi}{L}}\right]_0^{L/k}$$

$$= \frac{V_0 - V_B}{L}\left\{\frac{\sin\left(\frac{k+m}{k}\right)\pi}{2\pi(k+m)/L} + \frac{\sin\left(\frac{k-m}{k}\right)\pi}{2\pi(k-m)/L} + \frac{\sin\frac{m\pi}{k}}{\frac{m\pi}{L}}\right\}$$

for $m < k$ get (or $m > k$)

$$\frac{V_0 - V_B}{L}\left\{\frac{-\sin\frac{m\pi}{k}}{2\pi(k+m)/L} + \frac{\sin\frac{m}{k}\pi}{2\pi(k-m)/L}\right\} + \frac{\sin\frac{m\pi}{k}}{m\pi/L}$$

$$= \frac{V_0 - V_B}{2\pi(k^2 - m^2)}\left(2m\sin\frac{m\pi}{k}\right) + \frac{V_0 - V_B}{m\pi}\sin\frac{m\pi}{k}$$

$\frac{1}{m} + \frac{m}{k^2 - m^2} = \frac{k^2 - m^2 + m^2}{m(k^2 - m^2)}$

$$= (V_0 - V_B)\left(\frac{k^2}{m\pi(k^2 - m^2)}\right)\sin\frac{m\pi}{k}$$

If $m = k$, get $\left(\frac{2}{L}\right)\left(\frac{1}{2}\right)(V_0 - V_B)\left(\frac{L}{k\pi}\right)\left(\frac{\pi}{2}\right) = \frac{(V_0 - V_B)}{2k}$

If $2k > m > k$, get $\frac{V_0 - V_B}{L}\left\{\frac{\sin\left(\frac{m-k}{k}\right)\pi}{2\pi(k+m)/L} - \frac{\sin\left(\frac{m-k}{k}\right)\pi}{2\pi(k+m)/L}\right\} + \frac{\sin\frac{m\pi Z}{L}}{\frac{m\pi}{L}}$

$$= \left(\frac{V_0 - V_B}{L}\right)\left\{\frac{2m\sin\left(\frac{m-k}{k}\right)\pi}{2\pi(m^2 - k^2)/L}\right\} + = \frac{m\sin\left(\frac{m-k}{k}\right)\pi}{\pi(m^2 - k^2)}(V_0 - V_B)$$

agrees with above

* If m is a multiple of k, orthog. gives zero

Also change some time interval values as shown on 10/13/65 output of 65.502

10/13/65 10/14/65

Got manuscript off to good start. 6 typed pages plus Table I 10 equations

Now check over computer output.

65.502 Transient G ~~goofed~~ ran but there was an error proving importance of monitoring 14 & 15

1. Must put in Q dependence of $\lambda_{14,13}$ upon 11 in cols 58, 59
2. $\lambda_{15,13}$ 12 "
3. change amplitude min to 0, max to .09
4. change Keppas 2 to .5, 4, 6, 8 to .25, 13 to .025

65.603 paired chains trans. G

1. needs another 26 card or two

65.1522 change to 65.422 Square G fit
needs a control card ahead of the single "observed" value 100.

.01 at 42 this is std. dev.

1 at 57 this means std. dev.

65.1524 change to 65.424 Square G fit
Same need here

Coll first for semilog plot

Let $(V_0 - V_L) = V_L = 1.0$; $A = 0.1$

For $L = 4$, ~~set~~ I.C. = 1.0 in cpts 1, 2, 3, 4, 5, 6, 7

set $\lambda_{0,7} = 1.0$
$\lambda_{0,1} = 1.62$
$\lambda_{0,2} = 4.47$
$\lambda_{0,3} = 6.56$
$\lambda_{04} = 10.87$
$\lambda_{05} = 16.4$
$\lambda_{06} = 23.2$

set $\sigma_{8,1} = .05$
$\sigma_{8,2} = .0498$
$\sigma_{8,3} = .0495$
$\sigma_{8,4} = .0492$
$\sigma_{8,5} = .0487$
$\sigma_{8,6} = .0482$
$\sigma_{8,7} = 1.025$

L=2

$\lambda_{0,5} = 1.0$
$\lambda_{0,1} = 3.47$
$\lambda_{0,2} = 10.87$
$\lambda_{0,3} = 23.2$
$\lambda_{0,4} = 40.5$

$\sigma_{6,1} = .10$
$\sigma_{6,2} = .098$
$\sigma_{6,3} = .096$
$\sigma_{6,4} = .094$
$\sigma_{6,5} = 1.05$

Then can alternate signs for Z = L

65.741 L=4, Z=0, semilog
.742 L=4, Z=L, "
.743 L=4, Z=0 arithmetic
.744 L=4, Z=L arithmetic

65.721 L=2, Z=0 semilog
.722 L=2, Z=L "
.723 L=2, Z=0 arith
.724 L=2, Z=L arith

PlotCode for program (column 4)
1 semilog 2 page
2 semilog 1 page
3 arith 2 page
4 arith 1 page

See p78 for revised Table II

10/15/65

Got thru table II of paper & decided to setup simulation runs. Table I is on page 43

Table II is for A = 0.1 for Step-Nonuniformity pp 44-48

L/A = 2		L/A = 10	L/A = 20	L/A = 30	L/A = 40
		L = 1	L = 2	L = 3	L = 4
		A/L = .1	A/L = .05	A/L = .0333	A/L = .025
~~1~~	~~2A/L~~	~~.200~~	~~.100~~	~~.0667~~	~~.0500~~
.50					
.6466	$C_1/(V_0-V_L)$	.197	.100	.0665	.0500
0	$C_2/(V_0-V_L)$	.187	.098	.0662	.0498
−.2222	$C_3/(V_0-V_L)$	.172	.096	.0656	.0495
0	$C_4/(V_0-V_L)$	.151	.094	.0647	.0492
+.1273	$(C_0-V_L)/(V_0-V_L)$	.100	.050	.0333	.0250
				C_5	.0487
				C_6	.0482

Compare page 74 for exponential non-uniformity

If keep A/L = 0.1, then use first column only

∴ really, 1st col is L/A = 10, second is L/A = 20, L/A = 30, L/A = 40

Could reverse order to end with L/A = 2

65.503 Transient E peak of form p.28 with $A_0 = 2.718$
$a = 10.87$

which has peak = 1.0 at $T^* = \frac{.25}{2.718} = .092$

With Epeak = 2 in (2), peak in (2) = 0.086286 at T = 0.24 ± .01
peak in (1) = 0.08136 at T = 0.28 "

With Epeak = 20 in (8), peak in (8) = 0.4689 at T = 0.20 "
peak in (1) = 0.11027 at T = 0.88 "

Compare with earlier
65.501 where peak = 2.0 at $t^* = .046$ (G)
because $A_0 = 5.437$
$a = 21.75$

Then got peak in (2) ~~= 0.09962 at T = 0.20~~
= 0.1092 at T = .15 ± .025
peak in (1) = 0.09937 at T = .20 ± .025

---

peak in (8) = 0.5604 at T = 0.10 ± .025
peak in (1) = 0.09887 at T = 0.75 ± .025

---

note that faster transient of 65.501 (G) nearly had same peak ≅ .001 in (1)

& that slower transient of 65.503 (G) got less from (2)
more from (8)

presumably because (2) → (1) is more sensitive to peaks in (2)
whereas (8) → (1) is more sensitive to gain from less nonlinear loss

10/15/65 & 10/18/65 for comments written up
Got back four runs, studied & new submits.

65.422 Square G fit – almost worked – Trouble was that the 100. control card for std. dev. of "observed" point was not cleared immediately after G

Need to use	100.		42 st. dev.	57 1
observed	1.	time	value	
clear	100.		———	1

also, shifted peak to 26 and avoided extra data point because decimal precision makes two, therefore should break data generation at desired time value

65.424 made similar repairs & fixed a goof of its own
Both resubmitted.

65.603 paired chains with trans G
This worked, ~~to wish to reduce Koppa~~ fine, but summer opt. 17 got double epsp, not G.
Setup 65.604 with $\sigma_{17,10} = -1.0$ also $Koppa_{17} = 0.5$

later on try 65.605 controls with $\lambda_{6,15} = 0 = \lambda_{5,12}$ and $\lambda_{0,12} = -10.$

May soon wish to duplicate this deck & possibly fit for original G

65.503 was successful. Transient G in 2 and 8
see p. 64 655.12 But reduce $Koppa_8$ & $Koppa_{10}$ to 0.1
Setup 65.511 Transient G Fit for epsp peak = 0.10 also adjust time values

65.721 Nonuniform decay – Semilog plot at $Z=0$ for $L=2$

65.724 " " – Arith plot at $Z=L$ " "

Successful, now find back

65.~~7~~22 Semilog plot at $Z=L$ " "

& 65.723 arith. plot at $Z=0$ " "

May need to increase $(V_0-V_L)/V_L$?

Note for future 65.426 $\boxed{\begin{array}{llll} \lambda_{0,13} & 65. & 61. & 80. \\ \lambda_{013} & 31. & 30. & 35. \end{array}}$ 8

Restore 3 iterations peak occurs near $T=0.5$ .78

2.4 min ∴ take 65.422 [4] and after 1st 126. card have

1.	.26	new		after 1	.52		
200.	.01	as is	23.	200.	.02		11.
100.		as is		100.			.01 1
				1.	.76	.2	
				100.	.01		1 1
1.	.50	new .2		1.	.78		
				200.	.2		11.
100.		as is					1
1.	.52	as is					

Also change $\lambda_{13,2}$ to $\lambda_{13,6}$ [8] with 1 in col 60

$\lambda_{2,12}$ $\lambda_{6,12}$ [8] 1.24

& dependence relations

$\lambda_{2,12}$ to $\lambda_{6,12}$ [8] upon $\lambda_{0,13}$

$\lambda_{13,2}$ to $\lambda_{13,6}$ [8] " "

10/18/65 Got back five runs

65.422 Square G fit fit was perfect
$\mathcal{E}peak = 4.2036$ in 2
to give ~~V~~ peak = 0.2256 in 2 at T = .25
& epsp " = 0.200 in 1 at T = .26
But plotting scale was lousedup & will rerun as nonfitting replot with dummy time change to make max T = 1.1 instead of 2.2, Then $\Delta T = 0.01$ is OK for early part

65.424 Square G fit - perfect $\mathcal{E}peak = 10.567$ in 4
to give Vpeak = 0.3792 in 4 at T = 0.25
& epsp peak = 0.200 in 1 at T = .345
Rerun plot with dummy time change.

65.604 Paired Chains with Transient G

Unintended goof gave $Q_{17} = Q_5 - Q_{10}$
which gives difference between
→ hyperpolarized epsp in 5
& depol epsp in 10

But really meant to get $Q_{17} = Q_1 - Q_6$
to give difference at soma end.

10/19/65

Computation Series Recap

65.100	New Eq. Cyl. EPSP Series	3/17/65	Date begun
	Square G	10/5/65	
65.200	Applied Current Step & Square G	3/19/65	
65.300	Applied Current Sinusoidal & " "	3/30/65	
65.400 654.	Square G fit	10/11/65 – 10/15/65	
65.500 655.	Transient G (chain of 10)	10/5/65	
65.600 656.	Paired Chains with TRNS G	10/5/65	
65.700 657.	Non-Uniform Decay transients	10/15/65	

657.421 Needs 10 cpts. $\lambda_{0,10}$ is dummy for $V_0 - V_L$
8 & 9 are summers
7 is zero order
I.C. = 1.0 in cpts 1 thru 7
$\lambda_{0,10} = 2.$ to represent $V_0 - V_L$

0,7 = 1.
0 1 = 1.62
0 3 = 4.47
0 4 = 6.56
0 5 = 16.4
0 6 = 23.2

Make σ_{8j} & σ_{9j} for $j = 1$ to 7 dependent

Then $\sigma_{8,1} = 0.05\ \sigma_{0,10}$

2	.0498
3	.0495
4	.0492
5	.0487
6	.0482
7	.025 $\sigma_{0,10}$ + 1.0

$\sigma_{9,1} = -1.\sigma_{8,1}$
$9,3 = -1.\times\sigma_{8,3}$
$9,5 = -1.\times\sigma_{8,5}$
$\sigma_{9,2} = \sigma_{8,2}$

4	4
6	6
7	7

See p. 66

10/19/65

655.12 seep.64

Today got back $\boxed{\text{65.511 Transient G FIT}}$

This worked, but took 10 minutes & ran out of time before computing final solution & plotting.

655.12

Found E peak in (2) should be 2.50 to give epsp=.1 in (1)

(8) 17.30 " " " "

Rerun with these values & zero iterations

$\boxed{\text{Non-Uniform Decog}}$

Analysed 65.720 series & decided that should add a second summer & thus get Z=L & Z=0 simultaneously. Much less wasteful & more efficient. Renamed series 657.

Setup 657.421 L=4 $(V_0 - V_L) = 2$ rel to $V_L = 1$

also $A = 0.1$

After this is tested, can extend to others.

Square G, Plot of Previous Fit

65.422 & .424 needed 126. 0 1.

for second T.C. card to avoid neg. time values.

Resubmitted.

65.605 Paired Chains with TRANS G Worked.

But decided to have control simultaneous & difference against control

Will call this 656. Three Chains. C-STEP. TRNS G.

Should also prepare 657.221

Effect 5 min. per fit

10/20/65

Trans. G fit plot

655. Series

epsp peak in ①
perturbed cpt.

Printout of 65.571 — renamed 655.12
Convinced me to avoid time change & fit one at a time
Reduced to 15 cpts. & got rid of data points.

Setup 655.14 with dummy $\lambda_{015} = 4.5$ (4.0–6.0)
& fitting at $T = .36$

655.18 $\lambda_{05} = 17.3$ (17.2–17.4)
fitting at $T = .88$

657.421 Nonuniform Decay $L = 4$
$V_0 - V_L = 2$
$V_L = 1$

ran O.K. but needs minor
improvements to time values & ~~scale~~ amplitude scale
Fixed & resubmitted — Took 0.5 min

To take care of τ_7 or ~~faster~~ for $L = 4$, begin with $t = .06$

$$\tau_0/\tau_7 = 1 + \left(\frac{7\pi}{4}\right)^2 \simeq 1 + 30 \simeq 31$$
$$\tau_0/\tau_8 = 1 + (2\pi)^2 = 40.5$$

→ because $e^{-(31)(.06)} = e^{-1.86} \simeq .15$ and this/20 $\simeq .0075$ (.05/factor)
less than 1%

for τ_6, get $e^{-(23)(.06)} = e^{-1.38} \simeq 0.25$ & this/20 $\simeq .0125$

for τ_8, get $e^{-(40)(.06)} = e^{-2.4} \simeq .09$ and this/20 $\simeq .0045$

10/20/65 656.510 put in 10/20/65
means $\mathcal{E} = 10$ in cpt 5

Firstshot was 65.611 but had too many kappas &
exceeded limits. Take stock.

Cpts 1–5 1st chain, (+) current step, $\mathcal{E}$ in 5

" 6–10 2nd chain, (−) " ", $\mathcal{E}$ in 10

" 11–15 3rd chain, current step only.

Cpt. 16 is a ~~dump~~ sink for perturbed cpt. leak
17 is a summer $Q_{17} = \frac{1}{2}(Q1 - Q6)$
18 " " " $Q_{18} = Q_{11} - Q_{17}$
19 is source cpt. for constant current
20 is depleting source for transient G generator
21 is transient G time course
22 is source cpt. for $E\epsilon$

24 λ_{ij}
7 other λ not on λ
2 Sigmas in excess of summers
22 compartments (& hence on λ)
3 kappas minimum needed

58 which is less than 60

654. 10/20/65

10/20/65

65.422 & 65.424 now successfully plotted

Rename

654. Square G FIT

654.22 epsp peak = 0.2 in 1 for square ε ~~in~~ 2
$\varepsilon = 4.20356$ at $T = 0.20$

654.24 epsp peak = 0.2 in 1 for square ε in 4
$\varepsilon = 10.567$ at $T = .345$

Fit running time was 2.1 to 2.5 minutes

setup

See p. 57 & 39

654.26 expect $\varepsilon \approx 30$ ~~at~~ 6 ~~ep~~ peak $\approx$ ~~.6~~ .5

654.28 61 8 .76

plan

654.210 try $\varepsilon \approx 200.$, 100. to 500.
at $T = 1.0$

10/21/65

Received Terzuola, Shinas & Thomas-Greene manuscript.

Got back

655.140 A Transient G FIT PLOT

peak for E in 4 came in 1 at T = 0.44
although expected 0.36

∴ overshot in E ~~estimate~~ calc.
initial E = 4.5 was adjusted to 5.2256

Rerun as .141 B with weighted data point at T = 0.44
and λ_{015} range 5.1, 4.8 – 5.3

655.180 did not run because of minor card punching error $\lambda_{9,8}$ dependence relation missing

Take opportunity to anticipate peak shift from 0.88 to 0.96

Interpret peak shifts as due to transient E peak occurs ~~0.01~~ 0.08 after squarestep rise.

Goof

∴ 655.181 will incorporate this anticipation

657.421 Nonuniform Decay ~~Successful~~ did not run because put ahead of 26 card

In future, set up Kappa$_7$ = $\lambda_{8,7}$

Put in .001 value in col 27 for 7,8,9

Next setup 657.451 by changing $\lambda_{10,10}$ to 5.

For $M = 0.1$ $\quad (C_0 - V_L)/(V_0 - V_L) = 0.1/L$

and $\quad C_n/(V_0 - V_L) = \dfrac{0.2L}{L^2 + \left(\frac{n\pi}{10}\right)^2}$ $\quad \left(\frac{n\pi}{10}\right)^2 \to n^2(.0987)$

for $L = 1$

$n = 1$ gives $\dfrac{0.2}{1.098696} \cong 0.182$

$n = 2$ $\approx \dfrac{.2}{1.4} \approx 0.143$

$n = 3$ $\dfrac{.2}{1.9} \approx 0.105$

$n = 4$ $\dfrac{.2}{2.6}$ $\quad .077$

5 $\dfrac{.2}{3.5}$ $\quad .057$

$L = 2$

$\dfrac{.4}{4.1} \approx .0244 \approx .1$

$\dfrac{.4}{4.4} \approx .0227 \approx .09$

$\dfrac{.4}{4.9} \approx .0204 \approx .08$

$\dfrac{.4}{5.6} \approx .0178 \approx .07$

$\dfrac{.4}{6.5} \approx .0154 \approx .06$

$L = 3$

$\dfrac{.6 \ \cancel{.0667}}{9.1} \approx .0073$

$\dfrac{.6 \ \cancel{.0667}}{9.4} \approx .0071$

$\dfrac{.6 \ \cancel{.0667}}{9.9} \approx .0067$

$\dfrac{.6 \ \cancel{.0667}}{10.6} \approx .0063$

$\dfrac{.6 \ \cancel{.0667}}{11.5} \approx .0058$

$L = 4$

$\dfrac{.8}{16.1} \approx \cancel{.0031} \approx .05$

$\dfrac{.8}{16.4} \approx \cancel{.00305} \approx .049$

$\dfrac{.8}{16.9} \approx \cancel{.00296} \approx .047$

$\dfrac{.8}{17.6} \approx \cancel{.00284} \approx .0455$

$\dfrac{.8}{18.5} \approx .00270 \approx .0433$

$\dfrac{.8}{19.6} \approx \cancel{.00255} \approx .041$

$\dfrac{.8}{20.9} \approx \cancel{.00239} \approx .038$

$\dfrac{.8}{22.4} \approx \cancel{.00223} \approx .036$

Dorothy has done these more exactly on the Friden
See p. 74

Relevant to current applied at soma.

10/22/65 Exponential Nonuniformity

See p. 84 & 77

$$V(Z,0) = V_B + (V_0 - V_M)\, e^{-Z/A}$$

$$V_L = V_B + (V_0 - V_B)\, e^{-L/A}$$

Then $C_0 = V_B + \left((V_0 - V_M)/L\right) \int_0^L e^{-Z/A}\, dZ$

$$= V_B + (V_0 - V_B)(A/L)\left(1 - e^{-L/A}\right)$$

where for $L/A > 5$, $e^{-L/A} < .01$

$$C_n = \frac{2}{L} \int_0^L (V_0 - V_B)\, e^{-Z/A} \cos(n\pi Z/L)\, dZ$$

$$= \frac{2(V_0 - V_B)}{L} \left[\frac{e^{-Z/A}\left(\frac{n\pi}{L} \sin \frac{n\pi Z}{L} - \frac{1}{A} \cos \frac{n\pi Z}{L}\right)}{\left(\frac{1}{A}\right)^2 + \left(\frac{n\pi}{L}\right)^2} \right]_0^L$$

$$= \frac{2(V_0 - V_B)}{L\left(\frac{L^2 + (n\pi A)^2}{L^2 A^2}\right)} \left[e^{-L/A}\left(0 - \frac{(-1)^n}{A}\right) - 1\left(0 - \frac{1}{A}\right) \right]$$

$$= (V_0 - V_B)\left(\frac{2LA}{L^2 + (n\pi A)^2}\right)\left(1 - (-1)^n e^{-L/A}\right)$$

$$= (V_0 - V_B)(2LA) \big/ \left(L^2 + (n\pi A)^2\right) \quad \text{for } e^{-L/M} << 1$$

$$= (V_0 - V_B)(2A/L) \big/ \left(1 + (n\pi A/L)^2\right)$$

Compare back to pp 44–48 to step non-uniform

& p. 48–50 for cosine " "

& p. 54

cf. p. 74

Paper can introduce Table II, then point out that ~~steps~~ exaggerate higher order C_n unnaturally — hence consider exponential ~~or~~ cosine non uniformly.

---

note, here varying L with M constant —

Suppose it is R_m that is uncertain

Then should hold ~~M L cons~~ M/L & vary L

Then $M \cancel{L} = (0.1)L$ & vary L

For cosine dist, can have only second order term, for all half & half cases

p. 50, ~~[illegible]~~, k=1.0

Then $C_1 \cancel{A}(V_0 - V_L) = 1/2$

$C_0 = V_L + \frac{1}{2}(V_0 - V_L)$

$C_n = 0$ for $n > 1$

10/22/65

Table III

compare p. 54 Table II

exponential non-uniformity $M = 0.1$

	$L=1$	2	3	4
$(C_0 - V_B)/(V_0 - V_B)$	0.100	0.050	0.0333	0.0250
$2M/L$	~~0.200~~	0.100	0.0667	0.0500
$C_1/(V_0 - V_B)$	.182	.098	.0659	.0497
$C_2/(V_0 - V_B)$	.145	.091	.0639	.0488
$C_3/(V_0 - V_B)$	.106	.082	.0607	.0474
$C_4/(V_0 - V_B)$	.078	.072	.0567	.0455
$C_5/(V_0 - V_B)$	.058	.062	.0523	.0433
$C_6/(V_0 - V_B)$	.044	.053	.0478	.0409
	.034	.045	.0434	.0384
	.027	.039	.0392	.0358
	.025	.033	.0353	.0333
	.018	.029	.0318	.0309

But see new Table II on p. 78.

Maybe only cite 1st col. of this Table III in text to compare for $L/M = 10$

$V(Z,0) = V_L + \frac{1}{2}(V_0 - V_L)\left(1 + \cos(\pi Z/2A)\right)$ for $0 \le Z \le 2A$

with $2A \le L$

& preferably $L/2A$ an integer

Table III

Exponential shown in red

Cosine Nonuniformity

L/A	10	10	4	2
$(C_0 - V_L)/(V_0 - V_L)$	.10	.10	.25	.50
$C_1/(V_0 - V_L)$	.18	.20	.42	.50
$C_2/(V_0 - V_L)$	.14	.18	.25	.00
$C_3/(V_0 - V_L)$	.11	.16	.12	.00
$C_4/(V_0 - V_L)$	.08	.13	.00	.00
$C_5/(V_0 - V_L)$	.06	.10	-.01	.00
$C_6/(V_0 - V_L)$	.04	.07	.00	.00

$k = L/2A$

$\frac{L}{k} = 2A$

Case of $L/A = 10 = 1/2k$ is already done on page 49

for $L/A = 2$, have $C_1/(V_0 - V_L) = A/L = 0.5$, $C_n = 0$ for $n > 1$

for $L/A = 4$, compare n with $L/2A = 2$ $\therefore$ $n=2$ gives $\frac{C_2}{V_0 - V_L} = A/L = .25$

for $n=1$, get $\left(\frac{1}{\pi}\right)\left(\frac{1}{1-(.5)^2}\right)\sin\left(\frac{\pi}{2}\right) = \frac{1}{3/4\,\pi} = 0.424$

$n=3$, get $\left(\frac{1}{3\pi}\right)\left(\frac{1}{1-(1.5)^2}\right)\sin\left(\frac{3\pi}{2}\right) = \left(\frac{1}{3\pi}\right)\left(\frac{1}{-1.25}\right)(-1) = \frac{1}{3.75\pi} = 0.118$

$n=4$ gives zero, $n=5$ gives $\left(\frac{1}{5\pi}\right)\left(\frac{1}{1-(2.5)^2}\right)\sin\left(\frac{5\pi}{2}\right) = \left(\frac{1}{5\pi}\right)\left(\frac{1}{-5.25}\right) = -\frac{1}{26.25\pi} = -.012$

10/22/65 Suppose $M/L = 0.1$

& M increases with L, i.e. λ affects both.

from p. 72

Then $(C_0 - V_L)/(V_0 - V_L) = 0.1$ for all L

$$C_n/(V_0-V_L) = \frac{0.2\cancel{L^2}}{\cancel{L^2}(1+.0987n^2)}$$

$$= \frac{0.2}{1+.0987n^2} \text{ for all } L$$

perhaps set $M=A$

which is same as case for $L=1$, $M=0.1$

Return to cosine case, and consider only $k = 5$, 2 ~~and~~ 1, to compare with Table II p. 78

perhaps rename $k = \cancel{2A/2L} = L/2A$, then $\int_0^{2A}$

from page 50, we have $C_0 = V_L + (V_0 - V_L)(A/L)$

for $n \neq L/2A$

and $C_n/(V_0-V_L) = \left(\frac{k^2}{n\pi(k^2-n^2)}\right) \sin \frac{n\pi}{k}$

$$= \left(\frac{1}{n\pi(1-(\frac{n}{k})^2)}\right) \sin \frac{n\pi}{k}$$

for n = multiple of $L/2A$ get zero

for $n = L/2A$, get

$$= \left(\frac{1}{n\pi}\right)\left(\frac{1}{1-(2nA/L)^2}\right) \sin \frac{2\pi A}{L}$$

for $n = L/2A$, get $\frac{C_n}{V_0-V_L} = A/L$

i.e. for n not a multiple of $L/2A$, get $(1/n\pi)(1-(2nA/L)^2)^{-1} \sin(2\pi A/L)$

Exponential Non Uniformity
from pp 83+84

L/A		10 (from p74)	$\times \frac{V_0-V_b}{V_0-V_L}$	4	2	
C_1/V_0-V_b	.182	.309	.315	.288	.33	
C_2/V_0-V_b	.144	.144	.147	.092	.107	
C_3/V_0-V_b	.106	.0763	.078	.043	.05	
C_4/V_0-V_b	.078	.046	.047	~~.025~~ .0247	.0286	
C_5/V_0-V_b	.058	.0304	.031	.016	.0185	
C_6/V_0-V_b	.044	.0215	.022	.011	.0129	

C_0/V_L for $(V_0-V_L)/V_L = L/2A$ 1.5   1.46   1.35

$(C_0-V_b)/(V_0-V_b) =$ .1   .245   .4324

Exponential shown in red from p. 74

10/22/65

Revised Table II

Step Nonuniformity

ℓ/A	10	10	4	2
~~$(C_0 - V_L)/(V_0 - V_L)$~~	~~.10~~	~~.10~~	~~.25~~	~~.50~~
$C_1/(V_0 - V_L)$	.18	.20	.45	.64
$C_2/(V_0 - V_L)$	.14	.19	.32	.00
$C_3/(V_0 - V_L)$	.11	.17	.15	$-.21$
$C_4/(V_0 - V_L)$	.08	.15	.00	.00
$C_5/(V_0 - V_L)$	.06	.13	$-.09$	$+.13$
$C_6/(V_0 - V_L)$	.04	.10	$-.11$	.00

C_0/V_L	1.5	1.5	1.5
for $(V_0 - V_L)/V_L = \ell/2A$	5	2	1

for 65%. series

With $L/2A = 5$, $A/L = 0.1$, use $(V_0 - V_L)/V_L = 5$

$L/2A = 2$, $A/L = 0.25$, use $(V_0 - V_L)/V_L = 2$

$L/2A = 1$, $A/L = 0.5$, use $(V_0 - V_L)/V_L = 1$

The value of L determines the eigenvalues

The value of L/2A determines

and, given step, cosine, or exp, det C_n

10/22/65

655.141 successful $\mathcal{E}$ peak = 5.0086 in 4
togone epsp peak = 0.1 in 1
for T = 0.44

earlier 655.120 (p.62) $\mathcal{E}$ peak ≐ 2.50 in 2 T = .285

655.182 goofed $\mathcal{E} \approx 17.3$ redo → T = .86
see 65.512 within 1%
10/25/65 found 17.073

setup 655.161 try $\mathcal{E} = 10.$ at T = .60

Setup also
657.425 for L = 4, and ~~L/2A~~ 2 ≡ Cosine Nonlin
and 5 = L/2A
i.e. A/L = 0.1

using results on page 75 for C values
also fixed Kappa η dependent in right place

656.510 returned but without cards
erroneous to have summer 18 fed by summer 17
Need $\sigma_{18,1} = -.5$
$\sigma_{18,6} = +.5$
as well as $\sigma_{18,11} = 1.0$ as now
also will need $Kappa_{21} = .45$ and $Kappa_{18} = 50.$

10/22/65 got back

654.260 Squared Fit found $\mathcal{E} = 31.1$ in 6
to get spspeak $= 0.2$ in 1
at $T = 0.50$

654.280 something went wrong.
repair 200. card & range $\lambda_{0,13}$

657.221 was successful for old case of $L = 2$
$A = 0.1$
$V_0 - V_L = 2.0$

But no longer want this $A/L = .05$ is not really very important.

cf p. 78 versus p. 54

82

$$C_0 = V_b + (V_0 - V_b)(A/L)\left(1 - e^{-L/A}\right)$$

for $V_0 = 6V_L$

for $L/A = 10$, this is simply $V_L + (V_0 - V_L)(0.1)$ get $V_L + 0.5V_L$
$1.5 V_L$

for $L/A = 4$, & $V_0 = 3V_L$ } this is $0.96 V_L + (3 - 0.96)V_L)(1/4)(.982)$
$= (0.96 + (\frac{2.04}{4}).982)V_L = 1.46 V_L$
$.50$

for $L/A = 2$ & $V_0 = 2V_L$ } this goes $0.843 V_L + (2 - .843)V_L(\frac{1}{2})(1 - .1353)$
$= (0.843 + (1.157)(\frac{1}{2})(.8647))V_L$
$= (0.843 + 0.50)V_L = 1.34_3 V_L$

$$C_n = \cancel{V_b +} (V_0 - V_b)(2A/L)\left[1 + (n\pi A/L)^2\right]^{-1}$$

for $L/A = 10$, get same as before, on p. 72

for $L/A = 4$, $V_0 = 3V_L$ } get $\frac{C_n}{V_0 - V_L} = \left(\frac{3 - .962}{2}\right)\left(\frac{1}{2}\right)\left(\frac{1}{1 + (\frac{n\pi}{4})^2}\right)$
$= (1.02)\left(\frac{0.5}{1 + 0.617n^2}\right)$

$\frac{.5}{1.617} = .309$
$\frac{.5}{3.47} = .144$
$\frac{.5}{6.55} = .0763$
$\frac{.5}{10.87} = .046$
$\frac{.5}{16.42} = .0304$
$\frac{.5}{23.2} = .0215$

for $L/A = 2$ & $V_0 = 2V_L$ get $\frac{C_n}{V_0 - V_L} = \left(\frac{2 - .843}{1}\right)(1)\left(\frac{1}{1 + (\frac{n\pi}{2})^2}\right)$
$= (1.157)\left(\frac{1}{1 + 2.47n^2}\right)$
2.467

$n=1$ $\frac{1}{3.467} = .288 \times 1.157 = .333$

$n=2$ $\frac{1}{10.86} = .0922 \times = .107$

$n=3$ $\frac{1}{23.2} = .0431 \times = .050$

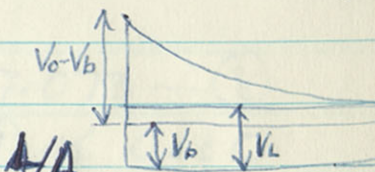
$n=4$ $\frac{1}{40.5} = .0247 \times 1.157 = .0286$

$n=5$ $\frac{1}{62.6} = .016 \times = .0185$

$n=6$ $\frac{1}{89.8} = .01114 \times = .0129$

10/25/65 Exponential nonuniformity

refer back to page 72, but fix V_L here for case $e^{-L/A}$ not neglig



Define $V(Z,0) = V_b + (V_0 - V_b)e^{-Z/A}$

where $V_L = V(L,0) = V_b + (V_0 - V_b)e^{-L/A}$

also $V_0 - V_b = (V_L - V_b)e^{+L/A}$ or $V_b = \dfrac{V_L - V_0 e^{-L/A}}{1 - e^{-L/A}}$

In particular, if $L/A = 10$, $e^{-10} \cong .000045$ & $V_b \cong V_L$

i.e. $(V_0 - V_L)/V_L = 2 = L/2A$

if $L/A = 4$, $e^{-4} = 0.0183$, and if $V_0 = 3V_L$

Then $\dfrac{V_b}{V_L} = \dfrac{1-3(.0183)}{1-.0183} = \dfrac{1-.0549}{1-.0183} = \dfrac{.945}{.982} = .962$

x1.02

or $3 - .962 \to 2.038$

.315 and $\dfrac{V_0 - V_b}{V_0 - V_L} = \dfrac{(1-.962)(54.6)}{2} = \dfrac{2.072}{2} = 1.018$

$\simeq 1.02$

.147

.078 i.e. $(V_0 - V_L)/V_L = 1 = L/2A$

.047 if $L/A = 2$, $e^{-2} = 0.1353$, and if $V_0 = 2V_L$

.031

.022 Then $\dfrac{V_b}{V_L} = \dfrac{1-2(.1353)}{1-.1353} = \dfrac{1-.2706}{1-.1353} = \dfrac{.7294}{.8647} = .843$

and $\dfrac{V_0 - V_b}{V_0 - V_L} = \dfrac{2-.843}{2-1} = 1.157 \simeq 1.16$

$V_0 - V_b = \dfrac{(1-e^{-L/A})V_0 - V_L + V_0 e^{-L/A}}{1 - e^{-L/A}}$

$= \dfrac{V_0 - V_L}{1 - e^{-L/A}}$

Use these results on p. 77

$\therefore \dfrac{V_b}{V_0 - V_b} = \dfrac{V_L - V_0 e^{-L/A}}{V_0 - V_L}$

Now have successful 654.220 Square 6 fits
.240
.260

Now have successful 655.18 Transient 6 fits
.14
.12

10/25/65 Got back

(Also phone call from Phil Nelson. Tom will visit Mon. Nov. 8 K & Phil no longer convinced of my arguments. See pp 10–18)

655.161 goof – incomplete change to cpd. 6

655.182 Transient G fit – Success $\mathcal{E} = 17.073$ in 8 for peak in 1 of 0.10 at $T = 0.86$

657.425 Nonuniform decay success for $L = 4$, cosine weight, $L/2A = 5$ $A/L = 0.1$

set up 657.422 for $L/2A = 2$, changed σ of $\lambda_{0,10}$ as needed

Next, set up 657. ~~222~~ .225

~~654.210 see p. 68~~

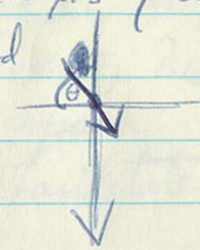
654.160 use 654.260 with change of data card & of λ

Try 655.110 try $\mathcal{E} = 50$, $45. \leftrightarrow 70.$ in 10 at $T = 1.$

10/26/65 Got letter from Brookhart on 10/22/65 in reply to mine of on 10/26/65 received refereeing job.

10/27 – 10/28 Spent time on refereeing job, dentist, & also a little on memo for Tom Smith, K., Phil & Roy.

Crux of refereeing job is that assumption ① the dipole, contradicts assumption ② axial symmetry around axis of cell, for all θ differing from $\pm\pi/2$, where θ defined



10/29 – 10/30/65

Roughed out referee memo & also memo for Smith et al.

Also measured & prepared new charts

→ 654.22, .424, .260 for Square G fit Series

→ 655.12, .141, .182 for transient G-fit Series

Charts are obviously incomplete

11/1/65

Got back batch of computations.
NBS computer had broken down.

656.511 Three chains. Step C. TRNS.G.
There was one too many Kappas, because of oddity
∴ drop $Kappa_{21}$
Also, unproved by making $\lambda_{5,22}$, $\lambda_{10,22}$, $\lambda_{0,22}$
$\lambda_{16,5}$, $\lambda_{16,10}$ all dependent
upon λ_{016}

Setup as 656.512

This facilitate adjusting $\mathcal{E}$.

655.161 Transient G fit plot

upper end of range
$\mathcal{E} = 55$ was much too much in 6

see p. 96

how did this happen?

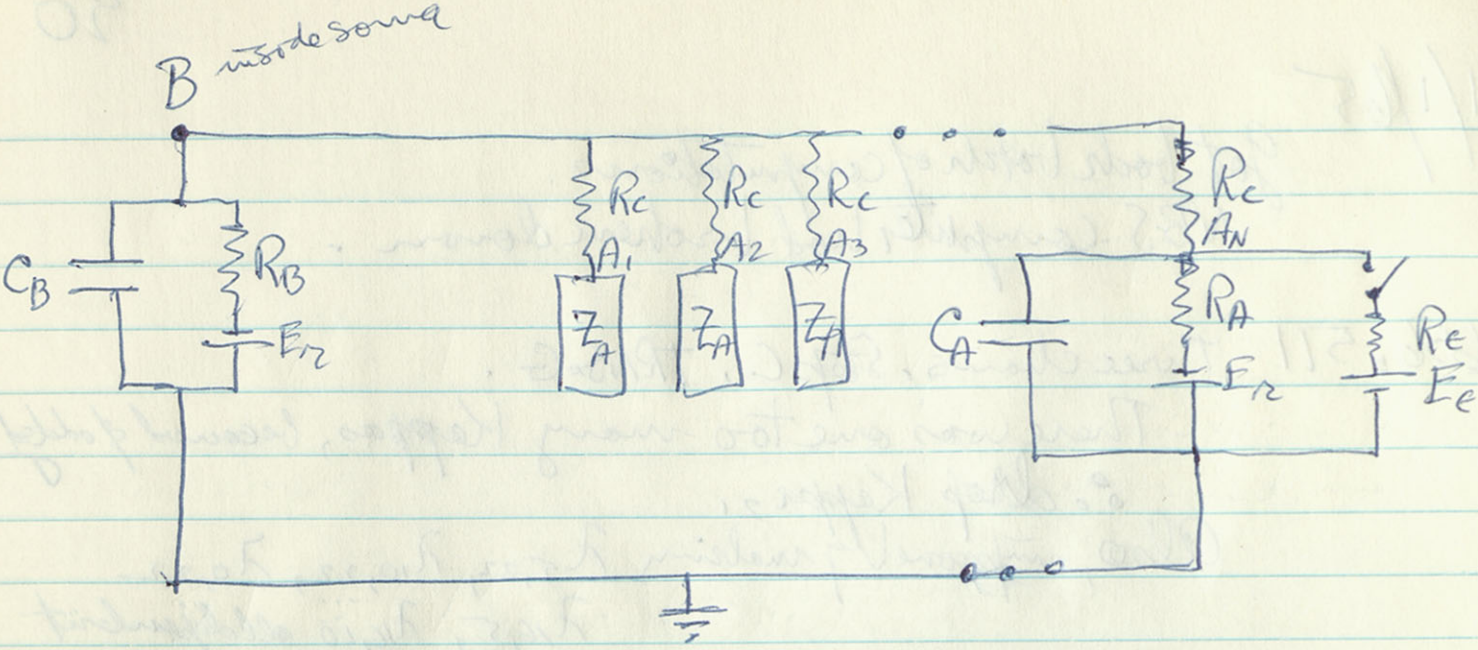
peak occurred at $T = .64$
set $\lambda_{0,15}$ 10. 5.–20.

655.110 $\mathcal{E} = 45$ was too much in 10 peak at 1.0
set $\lambda_{0,15}$ 40. 20.–45.

Square G plot fit

654.160 $\mathcal{E} = 9.67\frac{7}{2}$ in 6 to make epsp peak = .1 in 1
at $T = .51$
Successful

654.280 $\mathcal{E} = 150$ in 8 was not enough ∴ peak in 1 was .189
at $T = .74$
and peak in 8 was nearly saturated



R_B & C_B represent approx to soma transient response characteristics

R_A & C_A " " " axonal input " " " " "

If quantal epsp $\simeq \frac{1}{4}$ mV & typical epsp $\simeq 10$ mV, then have quantal number of approx 40 elements.

If max rate of epsp rise is ≈ 10 volt/sec & $\begin{cases} R_B \simeq 10^6 \text{ ohm} \\ R_B C_B \approx 2\times10^{-3} \text{ sec} \\ C_B \approx 2\times10^{-9} \text{ farad} \end{cases}$

then this rate of rise implies $C_B \frac{dV_B}{dt} = 2\times10^{-8}$ amperes

If driving pot. across parallel R_C is $\simeq 100$ mV, then one can deduce (assuming $R_E << R_C$) that $\sum G_C = 0.2\times10^{-6}$ mhos $= 40 G_C$

∴ each of 40 synapses has $G_C = 5\times10^{-9}$ mhos

or each $R_C = .2\times10^{9}$ ohms $= 200$ megs

11/4/65 – 11/5/65

Finished memo for K. Frank, Tom Smith, Phil Nelson, R. Wheeler
see p. 12 of this book & pp 89–115 of Book 6.

Attended Dick FitzHugh's seminar on his kinetic model, and lunch following. Mostly biophysics group.

Saw Dieter Lux, went over Lux & Pollen revised manuscript & Lux's questions regarding taper. He also tried but failed to include $\frac{ds}{dx}$ with $K \neq 0$ & apparently discovered the parabolic taper case also.

~~Now, check over latest computer output.~~

Crux of memo was that under resting conditions, the axonal input resistance, R_A, is sig. larger than the coupling resistance, R_C, and that during spike, axonal R_E is sig. smaller than R_C. This means that presynaptic action pot. does not simply apply a voltage, it applies a perturbation to the system. See bft for quantitative estimate of R_C. To estimate R_A consider from eq 10 of 1959 paper

$$R_\infty = \frac{\sqrt{R_m R_i}}{\frac{\pi}{2} d^{3/2}}$$

If $R_m R_i = 10^5 \text{ ohm}^2 \text{ cm}^3$

e.g. $R_m = 10^3$ ohm cm^2

$R_i = 10^2$ ohm cm

Then $\sqrt{R_m R_i} = 3.1 \times 10^2 \text{ ohm cm}^{3/2}$

$\simeq \pi \times 10^2 \text{ ohm cm}^{3/2}$

$\therefore R_\infty \simeq \frac{200 \text{ ohm cm}^{3/2}}{d^{3/2}}$

$= 10^9$ ohm

for $d = 1/3\,\mu$ gives $d^{3/2} = 200 \times 10^{-9}$ cm$^{3/2}$

Now consider t^* of epsp during I_p

$$V_B^* = E_r + I_p R_p + \Delta V_p$$

where $\Delta V_p > \Delta V_0$ by small amount

$$\Sigma I_c = (V_B^* - E_\epsilon)(N/R_c)$$

$$= (E_r - E_\epsilon + I_p R_p + \Delta V_p)(N/R_c)$$

for $\Delta V_p = 7$ mV & $I_p R_p = 30$ mV

This driving potential $V_B^* - V_A^* = -100 + 30 + 7 = -123$ mV

$$\Sigma I_c = -24.6 \times 10^{-9} \text{ amps.}$$

However current discharging C_B is

$$C_B \frac{dV_B}{dt} = G_B \Delta V_p + \Sigma I_c$$

$$= -17.6 \times 10^{-9} \text{ amps}$$

Ratio $\dfrac{dV_B/dt \text{ (with } I_p)}{dV_B/dt \text{ (without } I_p)} = \dfrac{E_r - E_\epsilon + I_p R_p + \Delta V_p (1 + G_B R_c/N)}{E_r - E_\epsilon + \Delta V_0 (1 + G_B R_c/N)}$

$$= 1 + \frac{I_p R_p + (\Delta V_p - \Delta V_0)(1 + G_B R_c/N)}{E_r - E_\epsilon + \Delta V_0 (1 + G_B R_c/N)}$$

$$= 1 + \frac{I_p R_p + 6(\Delta V_p - \Delta V_0)}{-70 \text{ mV}}$$

$$= 1 + \frac{-30 + 12}{-70} = 1.26$$

11/5/65

Thus the picture is $R_C/R_A \approx \frac{200\,\text{meg}}{1000\,\text{meg}} = \frac{1}{5}$

$R_C/R_E \simeq \frac{200\,\text{meg}}{10\,\text{meg}} = 20$

During and epsp, let t^* be time of max rate of rise & assume that $dV_A/dt = 0$ at this time.

$$V_B^* = V_B + \Delta V_0 = E_r + \Delta V_0$$

where $\Delta V_0 \approx 5\,mV$ e.g.

peak synaptic current

$$\Sigma I_c = (V_B^* - E_\epsilon)(N/R_c)$$

because $R_E << R_A$ and $R_E <<< R_C$.

Thus $\Sigma I_C = (E_r - E_\epsilon + \Delta V_0)(N/R_c)$

for $E_r = -70\,mV$
$E_\epsilon = 30\,mV$
$\Delta V_0 = 5\,mV$
$N/R_c = .2 \times 10^{-6}$ mho
$G_B = 10^{-6}$ mho

$V_B^* - V_A^* = -95\,mV$ The driving po

& $\Sigma I_C = -19 \times 10^{-9}$ amp

However $C_B \frac{dV_B}{dt} = +G_B \Delta V_0 + \Sigma I_C$
$= -14 \times 10^{-9}$ amp.

During applied ~~po~~ polarizing current I_p, first without epsp

$$V_B = E_r + I_p R_p$$

where $R_p = \left[G_B + \frac{N}{R_C + R_A}\right]^{-1} = \left[1.033 \times 10^{-6}\right]^{-1}$

Setup ipsp runs

11/5/65

In conclusion, this analysis shows that electrical synapse is not a current injection by a voltage source thru a high resistance. It is a perturbation which causes a synaptic current flow which does depend upon V_B and does provide a measurable conductance change in the postsynaptic element, for synapses at the soma.

* should run a somatic inhibition simulation to match ipsp amplitude to epsp amplitude

Now look at output

All entered in Summary Charts
11/5/65

655.162 Transient G fit — got $\mathcal{E} = 9.862$ in 6
for epsp peak of 0.1 in 1
at $T = .62$

655.110 — got $\mathcal{E} = 33.64$ in 10
for epsp peak of 0.1 in 1
at $T = 1.0$

654.140 Square G fit — got $\mathcal{E} = 4.409$ in 4
for epsp peak of 0.1 in 1
at $T = .35$

654.281 — $\mathcal{E} = 300.00$ in 8
for epsp of 0.200 in 1
at $T = .74$

11/5/65 Began exploratory plotting of non-uniform decay

11/8/65 Spend morning talking with Jose about his capillary computations.

11/9/65 Spend all day with K. Frank, T. Smith, Phil Nelson, Bob Burke.
They accepted most of memo, but thought they could justify a smaller value for R_A. They consider synaptic knob as a sphere of 2 to 4μ diam. I point out they could only use hemisphere.

Also from measurements of nodal resistances, they say. a cat node

1μ long
5 to 10μ diam.

Jerry Setton measured 10 meg.

$2\pi r l = \pi d l$

5μ diam gives $\approx 15\,\mu^2 \approx 15\times10^{-8}\,cm^2$; ~~$\frac{10^7}{15\times10}$~~

10μ diam gives $\approx 30\mu^2 \approx 30\times10^{-8}\,cm^2$; ∴

$R_m = 10^7 \times 15\times10^{-8} = 1.5\ \Omega cm^2$

$R_m = 10^7\times30\times10^{-8} = 3\ \Omega cm^2$

They said 3 to 15 Ωcm^2
But maybe this was referring also to a value of Tasaki.

I point out that maybe they should take C fiber λ and d as a better approach than nodal membrane.

Anyhow, hemisphere of 2μ diam has $A = 2\pi r^2 \approx 6.3\times 4\mu^2 \approx 25\mu^2$
$\approx 25\times10^{-8}\,cm^2$

4μ diam ⟶ $100\times10^{-8}\,cm^2$

Smaller one (2μ) is ≈ same surface area as node above, giving $R_A \approx 10^7$ ohm
larger (4μ) is ≈ 4 times, giving $R_A \approx 2.5$ meg. | They estimated 3 to 30 megohm

Evaluate C_N^{*} (effective) $= \frac{I_A}{\frac{dV}{dt}} = \frac{\sqrt{\pi T}\ \tau}{R_N e^{-T}}$ for several T

and for $\tau = 5\times10^{-3}$

$R_N = 10^6\,\Omega$

Thus, have $\frac{\sqrt{\pi T}}{e^{-T}} \times 5\times10^{-9}$ farad

for $T = .05$ get $\frac{\sqrt{.15}}{.95}\times5\times10^{-9} = 2\times10^{-9}$

$T = .1$ $\quad 3\times10^{-9}$

$T = .2$ $\quad \frac{\sqrt{.628}}{.82}\times5\times10^{-9} \simeq 5\times10^{-9}$

$T = .4$ $\quad \frac{\sqrt{1.25}}{.67}\times5\times10^{-9} \simeq 8.4\times10^{-9}$

This gives quantal I range as $\begin{cases} .6\times10^{-9} \text{ amperes} \\ 12\times10^{-9} \text{ amperes}\end{cases}$ for smallest rate of rise

and for Action Pot. of 60 to 85 mV

this gives R_C range $\begin{cases} \frac{.06}{12\times10^{-9}} = 5 \text{ megs} \\ \frac{.085}{.6\times10^{-9}} \simeq 150 \text{ megs}\end{cases}$

To reestimate R_C (coupling resistance)

11/9/85

Typical quantal size according to Kuno & Bob Burke, seems to be around 0.10 to 0.20 mV although sometimes as large as 0.7 mV or occasionally larger.

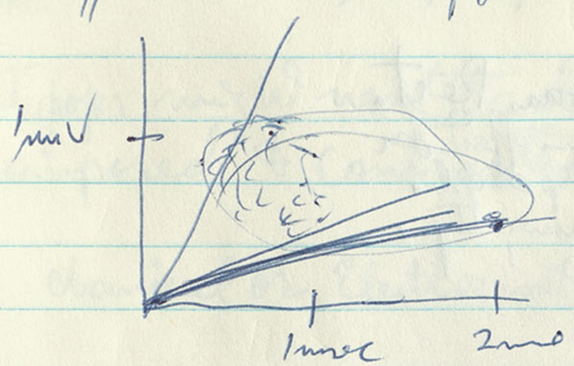
~~.02~~ .2 mV in .5 msec

Phil used 0.5 mV in 1.5 msec as overall rise time for 0.5 mV quantum
~~this~~ gives ~~average~~ rise rate of 0.33 volts/sec
but max rate of rise probably 1 volt/sec

Now, if $C_B = 2 \times 10^{-9}$ farad, this implies $I = 2 \times 10^{-9}$ amperes
and with 100 mV driving potential
this implies $R_C = \frac{10^{-1}}{2 \times 10^{-9}} = 50$ megohm

Phil estimated 50 to 150 megs

Actually, Bob Burke has a figure



overall average slope ranges from
.2 mV in 2 msec = .1 volt/sec
to 1 mV in ½ msec = 2 volt/sec.
If double for max slope
get range from .2 volt/sec
to 4 volt/sec

If ρ is very large, for current step $I_A R_N \frac{e^{-T}}{\sqrt{\pi \tau^2 T}} = \frac{dV}{dt}$

$$\text{or } I_A = \frac{\sqrt{\pi T}\, \tau \frac{dV}{dt}}{R_N e^{-T}}$$

If max rate of rise occurs at $t = 0.5$ msec, or $t/\tau = .1$ & $\tau = 5$ msec, get

$$I_A = \frac{\sqrt{.31}\; 5 \times 10^{-3} \text{ sec}}{10^6 \text{ ohm } (.9)} \frac{dV}{dt} \cong 3.1 \times 10^{-9} \text{ farad } \frac{dV}{dt}$$

See upper left

instead of earlier $C_N = 2 \times 10^{-9}$ farad

~~Soma~~

Somatic A	Somatic B		Dendritic A or B
>0	0	Impedance change	Small
+	0	Effect of Ip on epsp amplitude in absence of Anom. Rect.	small
+	0	Effect on max rate of rise	Small
short	short	epsp latency	not quite as short as somatic
high	high	epsp max rate of rise	not quite as high as somatic

Anom. Rect. main effect on epsp ampl. during Ip.

Experimentally have not made all the necessary observations on the same cell.

11/10/65

The upshot of all this is that one can argue that

They argued R_C range 50-150 megs : my est. was 200 megs
" " " R_A " 3 to 30 megs : " " " 1000 megs.

but I would like to check this against C fiber data.

But, if $R_C/R_A < 1$, then get closer to Toms const. current source.

for range of R_C/R_A values, I could simulate.

Test

$\frac{R_C}{R_A}$ values of 10, 4, 2, 1, .5, .25, .1

Joint paper might need to deal with six cases to be compared & contrasted.

A. chemical or Electric with $R_A >> R_C$

B. const. current source case of electric $R_A << R_C$

C. intermediate electric $R_A \simeq R_C$

A_1 somatic
A_2 dendritic
B_1 somatic
B_2 dendritic
C_1 somatic
C_2 dendritic

Typical exp. action potential 60 to 85 mV

overshoot 5 to 15 mV

resting pot. 50 to 70 mV

? leak around electrode ?

effect on initial steady state ?

11/10/65

Things to do. put E in ① and compare effects
on rate of rise, etc.
& on dectability of E

Note ~~For~~ experiments were with epsp ampl. 5 to 10 mV
or 1/10 to 1/5 of driving pot.
& hyperpol st-st. was 10 to 25 mV
or about twice epsp ampl.

Simulate epsp peak & rate of rise in the presence of steady state hyperpol.

11/10/65 Got back computations yesterday. Go over now.

556.510 Short Chain fit — input error

654.145 Square G fit
initial $g = 50.$ in (4) gave V peak $= -.0773$ in (4)
ipsp peak $= -.0444$ in (1)
at $T = .33$

max $g = 500.$ in (4) gave V peak $= -.0975$ in (4)
& ipsp peak $= -.06022$ in (1)
at $T = .32$

pretty close to limit

not worth pursuing.

infact 0.1 ipsp max is too much to ask if $\frac{E_r - E_j}{E_r - E_e} = .1$

∴ setup 654.545 aimed at ipsp peak $= .05$ in (1)

654.181 Square G fit $\varepsilon = 18.5$ in (8) to give ipsp peak of 0.10 in (1) at $T = .76$

655.165 transient G fit initial $g = 100.$ in (6) gave $-.0824$ in (6)
change to 655.565
& ipsp peak $= -.03265$ in (1)
at $T = .64$
time allowed exceeded at $T = 1.5555$
need to increase time factor to 1.0 in col. 2-10 of card 3

655.115
ran out of time at $T = .425$ because $\lambda_{10,10} = 426$
$\lambda_{15,15} = 400$
setup 655.525 instead

Next time, setup two chains & use I.C. & inflow rate of either 1.0 or 2.0

& have $\sigma_{22,I} = 1.0$

$\sigma_{22,II} = -1.0$

q.	T=1.0	St-st.
8	.0354	.0822
9	.0299	.0762
10	.0272	.0733

11/10/65 Begin 652.000 Series

first problem will be current step, calling for st. st. values and also for values at $T = 1.0$ to be used as I.C. for future problems where we put in the perturbations & obtain both transient & st. st. solutions for ~~Eq~~ Square

These will have only conductance changes.

652.001 Step C, Square G. need 11 gpts.
make I.C. in 11, be ~~1.31~~ 1.31786

652.002
22 gpts.

also put this in col 56-70 of I.C. for gpt. 1

.02 55.

11/12/65 found for $Q_{11} = 1.31786$ & inflow rate $= 1.31786$ that values can occur.

gpt.	T=1.0	St. St.
1	.1976	0.2485
2	.1551	.2057
3	.1210	.1712
4	.0939	.1435
5	.0726	.1215
6	.0563	.1044
7	.0441	.09147

11/12/65

See 652.001 previous page
revised to 652.002
Then will run together pert + unpert. steps from T = 1.0
& Sigma difference

556.510 Short Chain fit. found $\mathcal{E}$ = 12.49 in ⑤
gives epsp peak of 0.10 $^{1.003}$ in ①
at T = .95

556.511 Redo on finer time scale.

654.545 Square G Plot fit J = 79.232 in ④
pd in 25 for ②
to make ipsp = −.05 in ①
at T = .33

655.565 Transient G fit
pt in 66
J = 200. not enough in ⑥
must redo

655.525 Transient G fit J = 20.51 in ②
pd in 26
to refine
to make ipsp = −.05 in ①
at T = .26 to .28

$$V = C_0 e^{-t/\tau_0} + C_1 e^{-t/\tau_1} + C_2 e^{-t/\tau_2} + \cdots$$

$$\frac{dV}{dt} = -(C_0/\tau_0)e^{-t/\tau_0} - (C_1/\tau_1)e^{-t/\tau_1} - (C_2/\tau_2)e^{-t/\tau_2} + \cdots$$

$$\frac{dy}{dt} = \frac{d}{dt}(\ln V) = \frac{\frac{dV}{dt}}{V} = \frac{-(C_0/\tau_0)e^{-t/\tau_0} - (C_1/\tau_0)e^{-t/\tau_1} - \cdots}{C_0 e^{-t/\tau_0} + C_1 e^{-t/\tau_1} + \cdots}$$

as $t \to \infty$, this slope $\longrightarrow -\frac{1}{\tau_0}$

for $t \to 0$, this slope $\longrightarrow \frac{-(C_0/\tau_0) - (C_1/\tau_1) - \cdots}{C_0 + C_1 + \cdots}$

$$= \frac{-\sum (C_n/\tau_n)}{\sum C_n}$$

$$-\frac{1}{\tau_0}\left\{\frac{1 + (C_1\tau_0/C_0\tau_1) + (C_2\tau_0/C_0\tau_2) + \cdots}{1 + C_1/C_0 + C_2/C_0}\right\}$$

$$= -\frac{1}{\tau_0}\left\{\frac{1 + (\tau_0/C_0)\sum_{n=1}^{\infty}(C_n/\tau_n)}{1 + \frac{1}{C_0}\sum_{n=1}^{\infty}(C_n)}\right\}$$

If $S_0 = \left|\frac{\frac{dV}{dt}}{V}\right|_{t=0}$ & if $C_n = 0$ for $n > 1$

then $S_0 = \frac{C_0/\tau_0 + C_1/\tau_1}{C_0 + C_1}$

see page 116 for S_t

$$C_1/\tau_1 = (C_0 + C_1)S_0 - C_0/\tau_0$$

$$\tau_1 = \frac{C_1}{(C_0 + C_1)S_0 - C_0/\tau_0}$$

11/15/65 Consider sum of ~~two~~ exponentials.
Several approaches.

Suppose $Y = Ae^{-at} + Be^{-bt}$

consider $b > a$, $e^{-bt} < e^{-at}$

One approach is $Y = Ae^{-at}\left\{1 + \frac{B}{A}e^{-(b-a)t}\right\}$

~~Then~~ $y = \ln Y = \ln A - at + \ln\left\{1 + \frac{B}{A}e^{-(b-a)t}\right\}$

also $\ln Y_2 - \ln Y_1 = -a(t_2 - t_1) + \ln\left\{\frac{1 + \frac{B}{A}e^{-(b-a)t_2}}{1 + \frac{B}{A}e^{-(b-a)t_1}}\right\}$

$\frac{\Delta y}{\Delta t} = \frac{\ln(Y_2/Y_1)}{t_2 - t_1} = -a + \left(\frac{1}{t_2 - t_1}\right)\ln\left\{\quad\right\}$

suppose $(b-a)t_2 = 1$ and $(b-a)t_1 = 0.5$, then $\{\} = \left\{\frac{1 + 0.368\,B/A}{1 + 0.6065\,B/A}\right\}$

if also, $B/A = 1/5$, then $\{\} = \left\{\frac{1.0736}{1.1213}\right\} = 0.958$

$\ln\{\} = -.0429$

if $t_1 = 1$ msec, $t_2 = 2$ msec, then this contribution to slope is $-.0429\ \text{msec}^{-1}$

But, if have many points, fit by Mones' methods

Other approach $\frac{dY}{dt} = -aAe^{-at} - bBe^{-bt}$

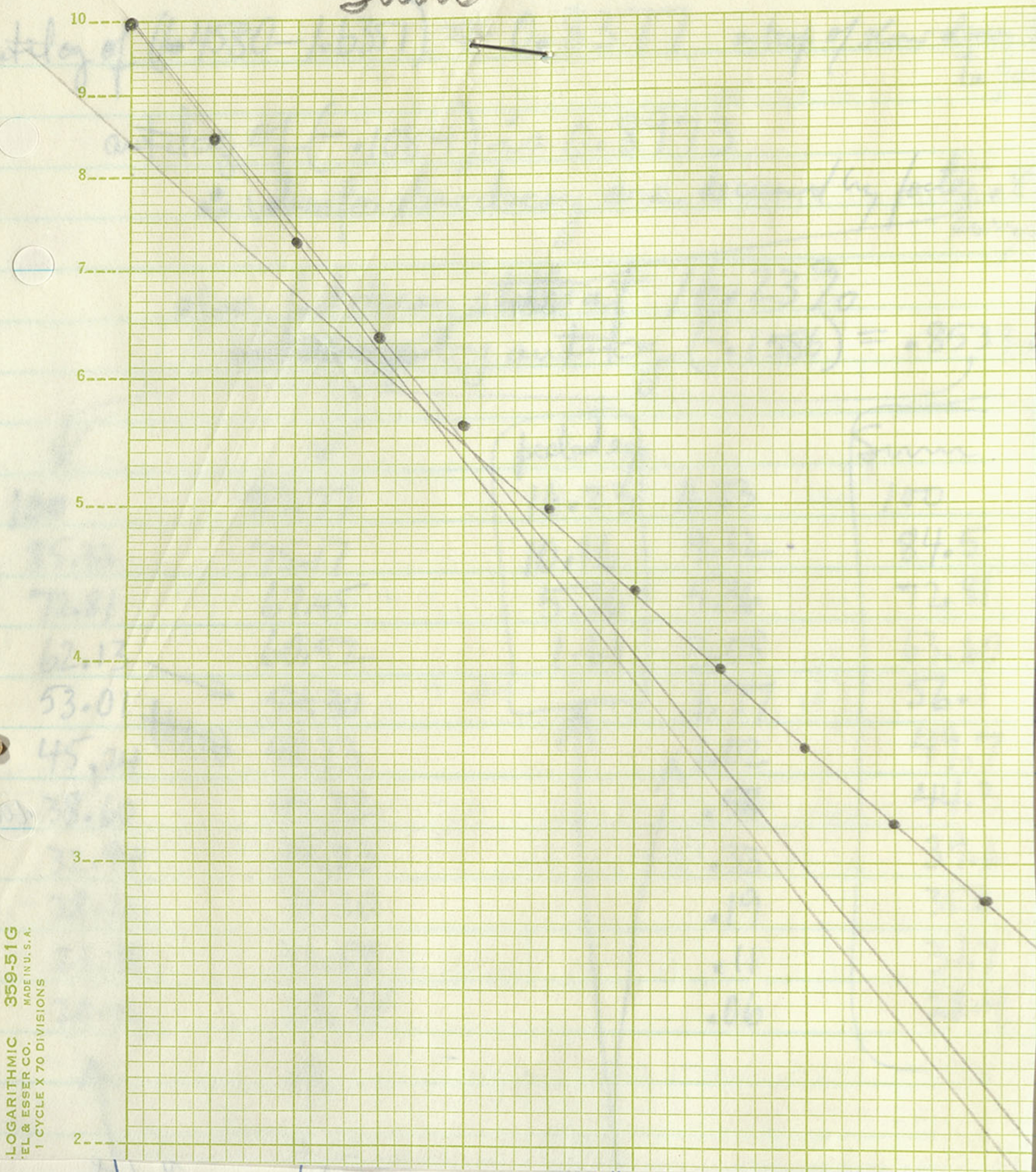
$\frac{dy}{dt} = \frac{d}{dt}(\ln Y) = \frac{\frac{dY}{dt}}{Y} = \frac{-aAe^{-at} - bBe^{-bt}}{Ae^{-at} + Be^{-bt}}$

$= -a\left\{\frac{1 + \frac{b}{a}\frac{B}{A}e^{-(b-a)t}}{1 + \frac{B}{A}e^{-(b-a)t}}\right\}$

as $t \to \infty$, slope $\to -a$

as $t \to 0$, slope $\to \left(\frac{-aA - bB}{A + B}\right)$

Sum



t
0
1
2
3
4
5
6
7
8
9
10

these are the two st. lines published by Fodiga & Brookhart

use factor $= \sqrt{\dfrac{1}{\frac{16.23}{5.136}}} = \dfrac{1}{\sqrt{3.03}}$

$= \dfrac{1}{1.74} = .575$

$= e^{-b}$

$b = \ln 1.74 = .554$

$\dfrac{C_1}{C_0} = \dfrac{16.23}{83.77} = 0.194$

?

p.178 suggests $0.1 < \dfrac{A}{L} < 0.25$

Sum


10
9
8
7
6
5
4
3
2
LOGARITHMIC
359-51G
MADE IN U.S.A.
1 CYCLE X 70 DIVISIONS

antilog of (-.4580 − 1.6351) = 83.77 extrap of slow decay back to zero

antilog of (−.1084) is 0.8973

∴ values for slow decay are decreased by factor .8973 every sec

also, fast decay starts at 16.23% ~~and decays~~ by antilog (−.1586) = .8533 every sec

t			peeled exp		Sum
0	100	83.77	16.23	16.23	100
1	85.33	75.17	10.16	9.32	84.5
2	72.81	67.45	5.36	5.36	72.81
3	62.13	60.52	1.61	3.08	63.60
4	53.01	54.30		1.77	56.1
5	45.24	48.73		1.02	49.7
6	38.60	43.72		.58	44.3
7	32.94	39.23		.33	39.6
8	28.11	35.20		.19	35.4
9	23.98	31.59		.11	31.7
10	20.46	28.34		.06	28.4

These are the two st. lines published by Todge & Brookhart

use factor $= \dfrac{1}{\sqrt{\dfrac{16.23}{5.36}}} = \dfrac{1}{\sqrt{3.03}} = \dfrac{1}{1.74} = .575$

$= e^{-b}$

$b = \ln 1.74 = .554$

$\dfrac{C_1}{C_0} = \dfrac{16.23}{83.77} = 0.194$

? (p. 178 suggests $0.1 < \dfrac{A}{L} < 0.25$)

11/16/65 As shortcut rough estimate instead of computer fit, take tail to get a & then extrapolate to zero to get A (C_0) & then actual initial value gives B (C_1).

Thus we have a, A, B & now we need b. If initial slope is reliable, we can get it thus

$$\to \text{mag} \equiv |S_0| = \frac{+aA+bB}{A+B} = \frac{C_0/\tau_0 + C_1/\tau_1}{C_0+C_1}$$

$$\therefore bB = (A+B)|S_0| - aA$$

See p. 120 for more general better relation

$$\frac{1}{\tau_1} = \frac{(C_0+C_1)S_0 - C_0/\tau_0}{C_1} \qquad b = \frac{(A+B)|S_0| - aA}{B}$$

Take data of Fadiga & Brookhart 1960 pp. 697 & 698

A+B ~~100%~~ (corresp to 100%) ~~[illegible]~~ $\ln(\text{A+B}) = 1.6351$

$A = 1.4580$

$B = 0.1771$

$a = +.1084$

$|S_0| = +.1586$

$$\therefore b = \frac{(1.6351)(.1586) - (+.1084)(1.4580)}{0.1771}$$

$$= \frac{.259 + .158}{.1771} = \frac{~~.417~~\ .101}{.1771}$$

$$= 0.570$$

from p. 43 τ_0/τ_1 implies $1 < L < 2$

this estimate gives $\tau_0/\tau_1 = \frac{.57}{.1084} = 5.26$

$\tau_0 = 9.2$ msec

$\tau_1 =$ ~~1.9 msec~~ 1.75 msec

114

Go back to p. 112

$$\ln(V_2/V_1) = -\frac{t_2-t_1}{\tau_0} + \ln\left(\frac{C_0 + C_1 e^{-(\frac{1}{\tau_1}-\frac{1}{\tau_0})t_2}}{C_0 + C_1 e^{-(\frac{1}{\tau_1}-\frac{1}{\tau_0})t_1}}\right)$$

$$\frac{\ln V_2 - \ln V_1}{t_2 - t_1} = -\frac{1}{\tau_0} + \frac{1}{t_2-t_1}\ln(\text{above})$$

Suppose we know τ_0, and $-S_{12} = \frac{\ln V_2 - \ln V_1}{t_2 - t_1}$ $\quad S_{12} > \frac{1}{\tau_0}$

and we want to get τ_1

$$(t_2 - t_1)\left(\overset{(\text{neg})}{\text{slope}} + \frac{1}{\tau_0}\right) = \ln(\text{above})$$

Working from two points: use essentially peel method.

$$C_1 e^{-t_1/\tau_1} = V(t_1) - C_0 e^{-t_1/\tau_0} = 10.16 \quad \text{peeled value}$$
$$C_1 e^{-t_2/\tau_1} = V(t_2) - C_0 e^{-t_2/\tau_0} = 5.36 \quad \text{"}\;\text{"}$$

$$-t_1/\tau_1 = \ln 10.16 - \ln C_1$$
$$-t_2/\tau_1 = \ln 5.36 - \ln C_1$$

$$\therefore \quad \frac{1}{\tau_1} = \frac{\ln(10.16/5.36)}{t_2 - t_1} = \frac{\ln(1.894)}{1\,\text{msec}} = .639\,\text{msec}^{-1}$$

$$C_1 = 10.16\, e^{t_1/\tau_1} = (10.16)(1.894) = 19.25$$

$$\tau_0/\tau_1 = \frac{.639}{.1084} = 5.9$$

$$\tau_1 = 1.565\,\text{msec}$$

at $t=1$ get

$$\frac{(.1635)(85.33) - (.1084)(75.11)}{10.16}$$

$$= \frac{13.95 - 8.15}{10.16}$$

$$= \frac{5.8}{10.16} = .571$$

11/17/65

If $S_t = \dfrac{C_0/\tau_0 e^{-t/\tau_0} + C_1/\tau_1 e^{-t/\tau_1}}{C_0 e^{-t/\tau_0} + C_1 e^{-t/\tau_1}}$

missed at first

If we have C_0, C_1, τ_0 & a preliminary est. of τ_1

Then we can refine τ_1 as

$$\tau_1 = \frac{C_1 e^{-t/\tau_1} \equiv V(t) - C_0 e^{-t/\tau_0}}{(C_0+C_1)S_t - (C_0/\tau_0)e^{-t/\tau_0}}$$

Apply this to Fadiga & Brookhart at $t = 2$ msec, $S_t = .1635$, $1/\tau_0 = .1084$, ~~$1/\tau_1 = .57$~~, ~~$C_0 = 83.77$~~, ~~$C_1 = 16.23$~~

However, if C_1 and τ_1 are uncertain, perhaps better not rely on them, better to replace $C_1 e^{-t/\tau_1}$ by the peeled value, which must be correct; but then, what should one use for C_1 in the denominator? Try both approaches & compare

$e^{-2(.57)} = e^{-1.14} = .320$

$e^{-2/9.2} = e^{-.2168} = .805$

$$\frac{16.23\, e^{-2/1.75}}{(100)(.1635) - (83.77)(.1084)e^{-2/9.2}}$$

recip

$\therefore$ get $\dfrac{1}{\tau_1} = \dfrac{16.35 - 7.3}{5.2} = \dfrac{9.05}{5.2}$

$5.36\, e^{2(.86)}$ 1.72

$\approx (5.36)(5.58)$

≈ 29.9

or $\dfrac{1}{\tau_1} =$ ~~Seems most useful~~

$$S_t = \frac{\frac{1}{\tau_0}(C_0 e^{-t/\tau_0}) + \frac{1}{\tau_1}\left[V(t) - C_0 e^{-t/\tau_0}\right]}{V(t)}$$

$$\therefore \frac{1}{\tau_1} = \frac{S_t V(t) - \frac{1}{\tau_0}(C_0 e^{-t/\tau_0})}{V(t) - C_0 e^{-t/\tau_0}}$$

Here avoid using C_1

Good if C_1 is unreliable

at $t=2$

$V(t) = 72.81$

$C_0 e^{-t/\tau_0} = 67.45$

$$= \frac{(.1635)(72.81) - (.1084)(67.45)}{72.81 - 67.45}$$

$$= \frac{11.92 - 7.32}{5.36} = \frac{4.6}{5.36} = .858$$

$\tau_0/\tau_1 = 7.92$ $\quad \tau_1 = 1.165$

This implies C_1 larger approx 30

116

From p. 46 for step ~~non~~uniformity

for A/L small, get $\frac{C_0}{C_1} = \frac{V_L + (A/L)(V_0 - V_L)}{2(A/L)(V_0-V_L)} = \frac{1}{2}\left\{1 + \left(\frac{L}{A}\right)\left(\frac{V_L}{V_0-V_L}\right)\right\}$

$= 0.5 + \left(\frac{L}{2A}\right)\left(\frac{V_L}{V_0-V_L}\right)$

for $A/L = \frac{1}{2}$, get $\frac{C_0}{C_1} = \frac{V_L + (A/2)(V_0-V_L)}{\frac{2}{\pi}(V_0-V_L)} = \frac{\pi}{4}\left\{1 + \frac{2V_L}{V_0-V_L}\right\}$

$= 0.785 + \frac{1.57\,V_L}{V_0-V_L}$

See p. 76

Cosine Case: for A/L small get same as above

for $A/L = 1/2$, get $C_1 = \frac{1}{2}(V_0 - V_L)$

$\therefore \frac{C_0}{C_1} = 1.0 + \frac{2V_L}{V_0-V_L}$

neatest

Exponential Case see pp 83 & 84

for A/L small, get same as above

for $A/L = 1/2$ get $C_0 = V_b + (V_0 - V_b)\left(\frac{1}{2}\right)(1 - .1353)$

$= V_b + (V_0 - V_b)(.43235)$

and $C_1 = \frac{V_0 - V_b}{1 + \left(\frac{\pi}{2}\right)^2} = \frac{V_0 - V_b}{3.467}$

$\frac{V_b}{V_0 - V_b} = \frac{V_L - .135\,V_0}{V_0 - V_L}$

$\therefore \frac{C_0}{C_1} \simeq 1.5 + \frac{3.47\,V_b}{V_0 - V_b}$

$= 1.5 + \frac{3.47\,V_L - .47\,V_0}{V_0 - V_L}$

---

for $L/A = 10$, get $\frac{C_0}{C_1} = .5 + 5\left(\frac{V_L}{V_0-V_L}\right)$ or $\left(\frac{V_0-V_L}{V_L}\right) = \frac{5}{\frac{C_0}{C_1} - .5}$

for $L/A = 2$, cosine case $\frac{V_0 - V_L}{V_L} = \frac{2}{\frac{C_0}{C_1} - 1}$

11/17/65 To summarize previous pages

Best fit to published points seems to be $83.77 e^{-t/9.2} + 16.23 e^{-t/1.75}$

However, if neglect value at $t=0$ as unreliable & take slope at $t=1$ μsec get almost the same, but if take slope $= .1635$ at $t = 2$ μsec

get $C_1 e^{-t/\tau_1} = 30 e^{-t/1.165}$

Whereas, if take only the two points at $t = 1$ μsec & $t = 2$ μsec (effectively) ~~somewhere between~~

get $C_1 e^{-t/\tau_1} = 19.25 e^{-t/1.565}$

Thus $\frac{C_1}{C_0}$ ranges from $\frac{.1635}{.8377}$ to $\frac{.30}{.8377}$

.194 to .36

$\frac{C_0}{C_1}$ $\simeq 5$ $\simeq 3$

While τ_0/τ_1 ranges from 5.26 to 8

comparing page 43, this lies between 3.47 for $L=2$

& 10.9 for $L=1$

Look at pp 78 and 75 for $A/L = \frac{1}{2}$, $\frac{C_1}{C_0 - V_L} = \frac{.50}{.50} = 1$ $\quad \frac{C_0}{C_1} - \frac{V_L}{C_1} = 1$

$\frac{C_0}{C_1} = 1 + \frac{V_L}{C_1}$

~~$\frac{C_0}{C_1} \simeq 5$ gives ≈ 1 for $\frac{V_0 - V_L}{V_L}$; $\frac{C_0}{C_1} \simeq 3$ gives ≈ 2 for $\frac{V_0 - V_L}{V_L}$~~

$\frac{C_0}{C_1} \simeq 5$ gives $\simeq \frac{1}{2}$ for $\frac{V_0 - V_L}{V_L}$; $\frac{C_0}{C_1} \simeq 3$ gives $\simeq 1$ for $\frac{V_0 - V_L}{V_L}$

11/17/65 Better notation

$$\text{Let } U = C_0 e^{-t/\tau_0}$$

$$\text{and } \cancel{g}\ h = \left|\frac{d}{dt}(\ln V)\right|$$

$$\text{Then } h = \frac{1}{V}\left[U/\tau_0 + (V-U)/\tau_1\right]$$

$$\therefore \frac{1}{\tau_1} = \frac{hV - U/\tau_0}{V-U}$$

Let $U = C_0 e^{-t/\tau_0}$ and $V = U + C_1 e^{-t/\tau_1}$

Text could read. It is well known that $\ln(V-U)$ vs t has a slope $-1/\tau_1$

~~To~~ This is basis for "peeling exponentials

However, suppose we know U and we know $h = \frac{d}{dt}(\ln V)$

Can ~~we~~ get τ_1 from this. Answer is yes, if we also know V

$$\frac{dV}{dt} = -U/\tau_0 - (V-U)/\tau_1$$

$$h = -\frac{d}{dt}(\ln V) = -\frac{1}{V}\frac{dV}{dt} = +\frac{1}{V}\left\{U/\tau_0 - (V-U)/\tau_1\right\}$$

655.526 has a mispunched card also

missing decimal point

resubmit 11/19/65

Wrote reply to Nastuk re Physiol. Rev. article.

11/18/65 Computations, refer back to p. 110 green indicates new submit

652.002 too many parameters ∴ revert back to 10 cpts

652.003 aim is to get st. st. & also values at T = 1.0 for I.C. in future runs.

— 65~~4~~.525 Transient G fit. There was a card mispunched & Susa's attempt to repair also goofed

65~~4~~.527 ∴ resubmit with correct card

655.566 Transient G fit, needs larger time factor. ran out at T = .418 because initial J = 300

previous .565 with J = 200 ran out at T = 1.66 & 4 end out late data points

.565 note J = 200 gave −.03792 at T = .68

.566 J = 300 gave −.04042 at T = .70

655.567 ∴ need to quadruple time factor & put data point at .70

556.511 Short Chain fit E = 12.40 in 5

transient G for epsp = 0.10 in 1 at T = .96

556.410 setup for E in 4

656.513 using E = 12.4 in 5

also deleting cpt. 21 monitor

add cpts 2, 3, & 4 for T = 1.0 data point

also, call for steady state inflow to 1.0

for st. st. values for future runs

11/24/65

652.222B

Steady State values

.25534
.18555
.15439
.12940
.10959
.094165
.082505
.074145
.068750
.066106 z

Wrong Jo,2 used

652.222A

Steady State values

1	.2744
2	.2054
3	.1709
4	.14322
5	.1213
6	.10422
7	.0913
8	.0821
9	.0761
10	.0732

11/19/65 Exp. Neurol galley proofs arrived yesterday
essentially O.K. – need to correct some references.

652.003 Step C with inflow rate = 2.0

cpts	Steady State Values		V at T = 1.0
1	.37710	1	.29992
2	.31218	2	.23535
3	.25975	3	.18360
4	.21771	4	.14248
5	.18438	5	.11024
6	.15843	6	.08542
7	.13881	7	.06689
8	.12474	8	.05375
9	.11567	9	.04534
10	.11122	10	.04125

Compare with pp 107-108 ~~for different inflow rate~~: seems to agree, as it should.

pert. cpt. — step inflow = 2.0

Setup 652.222 with $\lambda_{0,2} = 4.204$ — Should have been 5.204

.2 gpsp

I.C. as above for T = 1.0 & time range changed.

use $\lambda_{13,12} = 4.204$

~~652.242 λ = 10.57~~

~~pred-mi~~ T.C. & restore $\lambda_{0,2}$ to 1.0
with continuous time & step on.

$\lambda_{13,2} = 0$

at T = 2.0

cpt 1 gives .310717
cpt 6 gives − .310717
diff is .621434
cpt. 17 is 1/2 .310717
cpt. 11 .316366

cpt 18 = $\phi_{11} - \phi_{17}$ = .005649

11/19/65

556.410 Short Chain fit did not iterate because σ too small
however, learned max at T=.80

setup 556.411 with σ set .01 again &

656.513 Successful with ε=12.4 in 5 and 10

peak in Summer 18 was .005649 at T=2.0
but reached .0040 by T=1.60
from T.C. at 1.0
peak in 5 & 10 is at T=1.20
at that time 18 gives .00022

at T=2.0 cpt. 1 gives .410382
cpt. 6 gives -.211052
diff is .621434
cpt. 17 gives half this = .310717
whereas cpt. 11 gives .316366

and cpt. 18 = $\varphi_{11} - \varphi_{17}$ = .005649

% distortion = $\frac{.565}{.3164} \approx 1.8\%$

656.514
11/22/65 results

Control with I.C. = 0 in cpt 22
This sets $E_\varepsilon = 0$
& gives purely G perturbation
See if cpt. 18 comes out the same

yes it does, see left

11/19/65

655.567 Transient J fit J = 900 in (6) is not enough for ipsp = -.05 in (1)

Setup 655.510 fit J in cpt. 1 at T = .26
655.526 resubmitted at same time

654.527 Square J fit successful J = 15.338 in (2) for ipsp = -.05 in (1) at T = .26

Setup 654.510 (654.510 etc.)

11/22/65 setup 654.120

656.514 Three chain trans & control agrees with 1.513 (without E_e) (with E_e)

556.411 Short chain fit $\mathcal{E}$ = 7.3738 in (4) to make epsp peak = .1 in (1) at T = .80

652.222 Step C, Square G. using I.C. corresp. to T = 1.0 See p. 124
erroneous $\lambda_{0,2}$ set to $\mathcal{E}$ instead of $\mathcal{E}+1$
in future, use $\lambda_{13,j} = \mathcal{E}_j$

655.526 transient G fit J = 20.46 in (2) to make ipsp peak = -.05 in (1) at T = .27

655.510 ~~J = 14.83 in (1)~~ peak occurs at T = .20

~~656.410~~

~~I.C. Cards~~ ~~I.C.~~ ~~Inflow~~

pt. 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Got off *Exp. Neurol.* galley proofs

11/22/65

654.570 square J fit ~~J = 11.475 in 1~~

~~for peak ipsp = -.05 in 1~~

need to refit at T=.25

Need to set up

✓ 654.511 fit @ T=.25

✓ 655.511 fit @ T=.20

Still need to corrected 652.222 & others

put in

652.222 B

556.310

656.410 ~~Set up copy I.C. corresp. to T=1.0~~ ~~& calc fit~~ ~~steady state answers also.~~

no because trans G.

11/23/65

Got back

654.120 Square G fit $\varepsilon = 1.919_1$ in 2

to make $\varphi sp = .1$ in 1

at $T = .26$

654.511 Square J fit $J = 9.897_3$ in 1

to make $\varphi sp = -.05$ in 1

at $T = .25$

655.511 Transient J fit $J = 13.8655$ in 1

to make $i\varphi sp = -.05$ in 1

at $T = .20$

✓ Setup 654.130

✓ 654.110

✓ 655.110

✓ 655.530

✓ 652.242

652.003 Control values in ①

1.24	T= 1.25 est	1.26	1.28	1.30
.317645	.318270	.318896	.320117	.321 309
.270100	.269439	.269627	.272522	.276 325 ←
.047545	.048831	.049271	.047595	.044984

11/24/65 & 11/26

finished with engravers proofs, wrote Academic Press and Windle. Also did refereeing job for Windle.

11/26/65 Got back.

556.310 short chain fit was at $T = .80$
but should have been $T = .56$

✓ setup 556.311

652.222 B O.K. see back to page 124, where st. st. values are written down

in cpt. ① perturbed steady state value $= .25534$
compared with control $.37710$
$\Delta = .12176$

% decrease is $\frac{12.176}{.3771}$ = 32.3%

transient ~~dip~~ dip in ① due to perturbation in ② is 0.269439 at $T = .25 + 1.$
$.276325$ at $T = .30 + 1.$
$.269627$ at $T = .26 + 1.$

max dip % is $\frac{4.927}{.3189} = 15.45\%$

✓ setup 652.262 with $\lambda_{13,6} = 31.1$

656.410 Three chains, step C, trans G. Starting chart for these peak distortions (at $T = 1.80$) was 2.34%

Brought charts up to date.

• means put in 12/1

11/29/65 Taking Stock of Computations (using charts)

Square E with peak = .2 (654.200 series) Have 2, 4, 6, 8; need 1, 3 & 3 — 10 (your luggage)
I Step distortion by these (652.200 series) Have 2, 4, 6; need 1, 3 & 8

Square E with peak = .1 (654.100 series) Have 1, 2, 3, 4, 6, 8; need 10
I Step distortion by these (652.100 series) need all Have 4, 6, 1, 3
(have older ones, though)

Square J with peak = -.05 (654.500 series) Have 1, 2, 4; need 3 + ?6
I Step distortion by these (652.500 series) need all 4, 1

Transient E with peak = .10 (655.100 series) Have 2, 4, 6, 8, 10; need 1 & 3
I Step distortion by these (653.100 series) need all 1, 3

Transient J with peak = -.05 (655.500 series) Have 1, 2, 3; need 4 & ?6
I Step distortion by these (653.500 series) need all 1, 3

Square E on top of steady state hyperpol (654.108 series) need 1, 2, 3, 4, 6 8

Short chain, transient E with peak = .1 (556.000 series) have 3, 4, 5; need 1 + 2

Three chain series; step C, trans E (656.010 series) have 4 & 5; need 1, 2 & 3

Other parameter that could be changed is λij, determining chain length.
Other possible change is square E duration & trans. E duration.

11/29/65

654.130 Square G fit $\varepsilon = 2.9328$ in (3) to make epsppeak $= 0.10$ in (1) at $T = .29$

654.110 square $\varepsilon = 1.265$ in (1) to make epsp peak $= 0.10$ in (1) at $T = .25$

655.110 Transient G fit plot $\varepsilon = 1.7614$ in (1) makes epsp peak $= 0.10057$ in (1) at $T = .22$

655.530 $g = 34.58$ in (3) for ipsppeak $= 0.05$ in (1) at $T = .35$

652.242 Step C. Square G $\varepsilon = 10.57$ in (4)

		T= 1.26	1.30	T=1.34	1.38
st.st. control in (1)	.37710	.318896	.321309	.323612	.325809
st.st. with pert.	.27426	.293064	.292008	.293176	.295701
	Δ = .10284	.025832	.029301	.030436	.030108

27.3%

9.40%

1.32	1.36
.322474	.324723
.292358	.294327
.030116	.030396

Setup ✓655.111 with $\varepsilon = 1.75$ zero iterations & more time.

✓655.130

✓654.118 } epsp Square on top of steady state hyperpol.

✓654.138

✓654.210 ✓652.162

✓654.230 ✓652.142

11/29/65 late in day, got back

652.262 StepC square G $\mathcal{E} = 31.1$ in (6)

		T= 1.48	1.50	1.52	
st.st. control in (1)	.37710	.330881	.331828	.332754	652.003
st.st. with pert	.30033	.311977	.312871	.313807	
Δ =	.07677	.018904	.018957	.018947	
	20.3%		5.72%		

556.311 Short chain fit $\mathcal{E} = 4.1316$ in (3)
to make epsp = 0.10 in (1) at T = .56

setup + print in ✓556.210 short chain fit
✓656.310 3 chains.

12/1/65 Got back 10 decks & output

654.230 erroneous 200. cards resubmit
654.210 erroneous 70 card resubmit
654.118 Square G PLUS C. St.St. hyperpol. epsp peak = .1377
654.138 " " " .1261
setup 654.128
654.168

Need to measure changes in slope etc.

556.210 short chain TRNS G fit $\varepsilon = 2.1086$ in 2 of five to make epsp = .1 in 1 at T = .40
setup 556.110

656.310 Three chains. Step C. TRNS G. with $\varepsilon = 4.1316$ in 3
get peak distortion = 3.63%
setup 656.210

652.142 Step C, Square G with $\varepsilon = 4.409$ in 4

		T = 1.34
st.st. control in 1	.37710	.323612
st.st. with pert.	.31175	.308443
	.06535	.015169
	17.3%	4.7%

setup 652.542

652.162 $\varepsilon = 9.677$ in 6

		T = 1.50
control	.37710	.331828
with pert.	.32362	.322414
	.05348	.009414
setup 652.512	14.2%	2.84%

12/1/65 & 12/2/65

655.130 TRNSG found $\mathcal{E} = 3.5467$ in (3) to make epsp peak = .1 at T = .36

655.111 TRNSG found $\mathcal{E} = 1.075$ in (1) to make epsp = .1 at T = .22

setup 653.132 TRANSG, with StepC
653.112

12/2/65 No computer output — NBS computer was down
However got my ten decks of cards back.
∴ Decided to have them duplicated.
Just now completing interpreting these cards.
Now can setup new runs for 9AM tomorrow pickup

Need to setup

setup 12/2

- 652.112 ✓
- 652.212
- 652.232
- 652.132 ✓
- 653.532 ✓
- 653.512 ✓
- 655.540 ✓
- 655.560
- 654.148 ✓
- 654.188 ✓
- 654.110 ✓ Had a wrong card in for λ 104

658. series based on 655 but with doubled duration.

12/3/65 Got back output of ten problems put in 12/1/65

654.128 Square G on steady state hyperpol. $Q_{11} = .1312$ at $T = .26$
agrees with 1.312 driving pot in (2)

654.230 Square G fit $\varepsilon = 7.00$ ~~in (3) to make~~
wrong 704 card
~~epsp peak = 0.2 in (1) at T = .29~~

556.110 Short chain fit — misjudged peak time; it is .25
414
176
2174 Resubmit
$\varepsilon = 1.0$ in (1) gives peak $= .0958644$ at $T = .26$
$\varepsilon = 1.2483$ " " $.1176$ at $T = .25$
guestimate $\varepsilon = 1.047$

654.210 Square G fit $\varepsilon = 2.763$ in (1) to make
epsp $= 0.2$ in (1) at $T = .25$

654.168 Square G on steady state hyperpol $Q_{11} = .11587$
at $T = .51$
agrees with 1.1584 driving pot in (6)

656.210 Three chains with $\varepsilon = 2.1086$ in (2)
peak $Q_{18} = .017468$ at $T = 1.40$
peak $Q_{11} = .2933$ " "
5.96 % distortion

652.542 Step C, $J = 79.23$ in (4)

st st. control	.37710	at $T = 1.34$ control $=$	.323612
st st. with pert.	.21748	with pert.	.246873
	.15962		.076739
	42.4%		23.7%

T = 1.16

.283407

12/3/65

652.510 $J = 9.897$ in (1)

1.24	1.26
.317645	.318896
.162716	.174377
.154929	.144519

st.st.control .37710
pert .13157
.24553
65.1%

est. see p. 133
control J T=1.25 is .318270
pert .161437
.156833
49.2%

653.132 transient E peak = 3.5467 in (3)

T=1.26
control .318896
.301347
.017549
5.5%

st.st.control .377097
pert.control .298206
.078891
21%

T=1.36
.324723
.305178
.019545
6.02%

653.112 transient E peak = 1.075 in (1)

~~st.st.~~
st.st.control .377097
pert.control .28354
.093557
24.8%

T=1.22
control .316363
pert .285298
.031165
9.84%

~~at 1.25~~
~~.318270~~
~~.287456~~
~~.030814~~
~~9.7%~~

later 12/3/65

These eleven decks went in
9 AM
12/6/65

652.282
~~65[illegible].118~~ already have
~~65[illegible].138~~
655.128
655.168
~~6[illegible].212~~
653.162
652.122
652.212
652.522
653.122
653.142
652.232
655.550
eleven decks

12/3/65

Setup

There four were picked up in the afternoon of 12/8/65

These four decks came back 12/6/65 without output

✓ 556.110 rerun with test T = .25

✓ 656.110

~~✓ 65[illegible].282~~

wrong ✓ 654.530 ✓ 654.560

Refer back to page 135 & update.

654.200 Square E (peak = .2) Have 1, 2, 3, 4, 6, 8 (10 too much)
652.202 Step C distortion Have 2, 4, 6; need 1, 3 & 8

654.100 Square E (peak = .1) Have 1, 2, 3, 4, 6, 8, 10
652.102 Have in 1, 3, 4, 6 need 2, 8, 10

654.500 Square J (peak = -.05) Have 1, 2, 4, put in 3, 6
652.502 Have 1, 4, need 2, 3, 6

655.100 Transient E (peak = .2) Have 1, 2, 3, 4, 6, 8, 10
653.102 Have 1, 3, need 2, 4, 6, 8, 10

655.500 Transient J (peak = -.05) Have 1, 2, 3, 4, 5 need 6?
653.502 Have 1, 3, need 2, 4, 6

654.108 Square E upon steady state hyperpol. Have 1, 2, 3, 4, 6, 8

656.000 Short chain Trans E with peak (.1) Have 1, 2, 3, 4, 5

656.000 Three chans, have 2, 3, 4, 5 & put in 1.

655.108 Trans E upon steady state hyperpol. Need all 2, 6

Wh

12/6/65
Discovered erroneous 704 card in decks
that were recently used for 654.230, 654.530
654.110

Got back four decks this morning, without output.
Put in
654.111 with ~~704~~ corrected
654.530 " " "

Output due today was not brought by messenger.
Phil Nelson called — we will get together Wednesday

Take stock of present charts & plots. Have 9 charts & 2 summary plots.

654.1 Plot Summary
(a) 10% to 90% of peak ΔT shows artefactual flatness
(b) rising ½ max to falling ½ max shows ~~steep~~ & linear rel.
(c) ~~$\frac{dV}{dt}$~~ at rising half max shows artefactual flatness & then falls.

Output came in now.

Compartment 12 was not handled correctly

12/6/65 3:20 PM, finally got back computer output
Four from 12/3/65 (see p. 146 green)
Eleven from this morning p. 145

556.111 Short Chain fit $\mathcal{E} = \cancel{10.}\ 1.04558$ in ①
gives epsp peak = .10 at T = .25

656.110 Three chains: Used $\mathcal{E} = 1.047$ in ① which agrees to 1 pp thousand
peak $\varphi_{18} = .0277913$ at T = 1.25
$\varphi_{11} = .284706$ at T = 1.25
9.76% distortion

Koppa 18 was too big for prettiest plot. Could rerun with smaller Koppa & also with inflow to get st.st. answer.

654.560 error in I.C. in 12, should be −.1
resubmit with this fixed
654.561

654.530 had erroneous ~~To4~~ card
Correction has already been submitted earlier today

652.282 Step C, Square E ~~peak~~ = 300. T = 1.74

st.st.	.37710	control	.341712
per ~~control~~ st.st.	.32488		.328960
	.05222		.012752
	13.9%		3.73%

? 655.128 TRANS G. on St St. C.
φ_1 min = .345858 at T = .29
Driving pot is 1.31218
φ_{11} peak = .~~03~~ 3124 at T = .29 Not what I expected

12/6/65

655.168 TRANS G on st.st. driving pot = 1.15843

? peak Q_{11} = .0158636 at T = .62

min Q_1 = −.361236 at T = .62

Same puzzling result.

Compartment 12 was not handled correctly

see p. 166

Must resubmit with new dates.

653.162 Step C, trans E peak = 9.862 in ⑥

Resubmit error on card

~~contrl st st .3771 at T = .62 .337092~~

~~pert st .3058 .326756~~

~~.0713 .010336~~

~~18.9% 3.06%~~

653.122 Step C, trans E peak = 2.5 in ②

st st contrl .3771 T = .28 .320117 contrl

.29044 .295454

.08666 .024663

23% 7.7% ~~10.83%~~

653.142 — E = 5.01 in ④

.3771 T = .44 .328921 1.44

.30645 .313481

.07065 .015440

18.7% 4.7%

12/6/65

652.522 $\varepsilon = 15.338$ in (2)

	.3771	T=.26	.318896	1.26
st st.	.1629		.194971	
	.2142		.123925	
	56.8%		38.9%	

652.232 used incorrect $\varepsilon = 7.00$ value from 654.230 which had wrong 204 card.

652.212 $\varepsilon = 2.763$ in (1)

st st.	.3771	T=.25	.318270
	.2479		.255775
	.1292		.062495
	34.3%		19.6%

655.550 TRANS J fit $J = 146.47$ in (5)
for $\varepsilon_{sp} = .05$ in (1)
But run was cut off.

Need to setup 655.551 simulation

653.532 $J = 34.58$ peak in (3)

st st.	.3771	T=.36	.324723
	.18387		.228164
	.19423		.096559
	51.6%		29.8%

652.132 $\varepsilon = 2.933$ in (3)

		T=.28	T=.30
.3771		.320117	.321309
.3078		.300850	.301947
.0693	18.4%	.019267	.019362
		6%	

Still to do

655.128
655.168 } resubmitted

654.1 10 is in
654.2 10 put in when above returns; 654.230 is in
654.5 3 + 6 are in; consider 5, 8, 10

652.1 need 4, 6, 8, 10

652.2 need 3 652.182 532 232 must wait
.162
652.5 need 3, 6? .142

654.108 complete

655.100 ~~complete~~
655.5 try 5 + 6

656. Complete except for cosmetics & stats

653.1 need , 4, 653.162

653.5 need 2, 4 653.522
653.542
653.552

12/6/65

652.112 $\varepsilon = 1.265$ in (1) $T = .25$

st.st. .3771 .318 270

.3045 .287 052

.0726 19.25% .031 218

9.8%

653.512 J peak $= 13.866$ in (1) $T = .20$

.3771 .315 050

.1043 .159 512

.2728 72.4% .155 538 49.4%

654.188 $\varepsilon = 18.498$ in (8) upon st.st. hyperpol.

$\varphi_{11} = .1126$ at $T = .77$ drivpot. = 1.125

654.148 $\varepsilon = 4.409$ in (4) 1.2177

$\varphi_{11} = .12176$ at $T = .35$

654.110 Erroneous card, already resubmitted

655.540 Found J peak $= 72.24$ in (4)

makes epsp peak $= -.05$ in (1)

at $T = .445$

652.122 $\varepsilon = 1.919$ in (2)

$T = .26$

.3771

st.st. .3058 .318896

.0713 .294291

18.9% .024605

7.72%

More generalizations, for a given epsp peak amplitude & location of perturbed compartment, the square pert. requires ~~less~~ E smaller E than does the TRNS pert, for locations 1-6 and reverse for 8 & 10

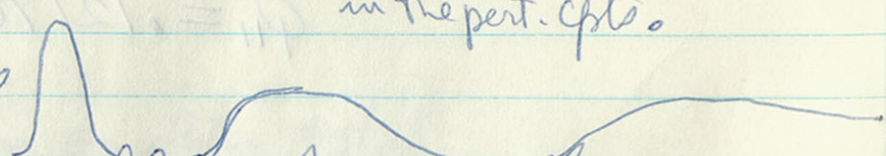
	□ 10 epsp peak	TRNS	factor	Time of lat
1	1.265 .25	1.75 .22	.723	
2	1.919 .26	2.50 .28	.768	
3	2.933 .29	3.546 .36	.828	
4	4.409 .35	5.01 .44	.886	
5				
6	9.677 .51	9.862 .62	.98	
7				
8	18.498 .76	17.07 .86	1.085	
9				
10	? 55. .88	33.64 1.0	1.63	

Early effect due to square pulse packing in more current early.

Late effect due to better temporal summation of less intense, longer lasting change.

Useful to compare peaks & durations in the pert. cpts.

Predict that if compare perturbations



all with equal areas

Sharpest will be most effective near soma
slowest will tend to be most effective in periphery.

Square one has two features of sharpness (1st early rise, absence of tail)

12/7/65

What kinds of generalizations are possible now?

<u>Given</u> Square $\mathcal{E}$ of standard $\tau/4$ duration at various locations.

$\frac{dV}{dT}$ at rising half max ranges from .44 to .28 from 1 to 8 for (.10)
less than factor of two

want to express as

654.1 series $\frac{\frac{dV}{dt}}{V} = \frac{\frac{dV}{dT}}{\tau V} = \frac{.44}{(.1)5\,\text{msec}} \simeq 1$ per msec to $\frac{1}{2}$ per msec

654.2 series $\frac{.95}{.2(5)} \approx 1$ per msec to $\frac{.541}{.2(5)} \approx \frac{1}{2}$ per msec

654.5 series $\frac{.32}{.05}(5) \simeq 1.2$ per msec

654.108 series $\frac{.62}{.1}(5) \simeq 1.2$ per msec

655.1 series $\frac{.76}{.1}(5) \simeq 1.5$ per msec

655.5 series $\frac{.49}{.05(5)} \simeq 2$ per msec

See pp 23-28

For particular TRNS used $B = aA_0te^{-at}$ with area under curve $= \Delta T = \frac{A_0}{a}$

if peak is to be 1, then $A_0 = e$, $a = \frac{e}{\Delta t}$

$B = \boxed{\frac{e^2}{\Delta t}} te^{-\frac{et}{\Delta t}}$

or $B = aete^{-at}$ with $a = \frac{e}{\Delta t}$

$= ate^{(1-at)}$

$\Delta t = \frac{.25}{}(5) = 1.25$ msec

$a = \frac{2.718}{1.25} = 2.175$ msec^{-1}

∴, I have been using $\frac{\mathcal{E}}{\mathcal{E}_{max}} = 5.91\,te^{-t/2.175}$

where t is expressed msec

St. St.

i.e. here 175% increase of G_S

causes 33% increase of G_N

or 25% decrease of R_N

Transient decrease

≡ peak distortion ≃ 10%

see 653.112 on page 146

12/7/65 Got back two outputs, cords that were corrected pp 148

654.531 found $J = 28.424$ in 3
to make ipsp peak $= -.05$ in 1 at $T = .28$

654.111 found $\mathcal{E} = 50$ in 10 almost enough for
epsp $\doteq .1$ in 1, actually .09696
at $T \doteq .88$

setup
654.231 ✓ got back 12/9/65
652.532 ✓
654.112 opt 10 ✓
652.102 opt 10 ✓
656.111 ✓

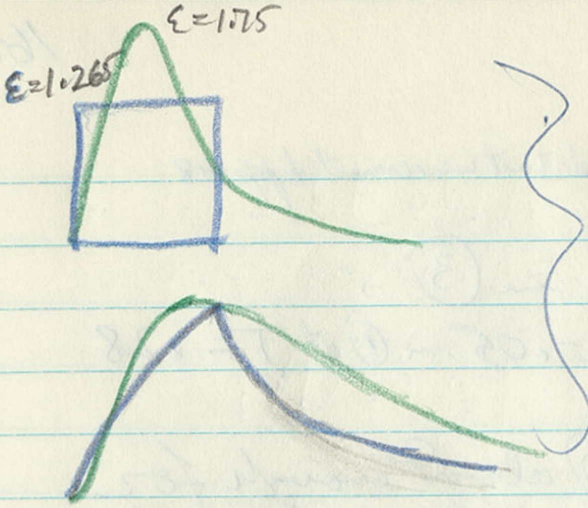
From current step control 652.003, can compute
that $\rho = 4.3$ for 1 as soma, versus rest.

st-st. current from 1 to 2 $\propto 25(.3771 - .3122) = 1.62$
st-st. leak current from 1 $\propto .3771$

$$\therefore \rho = \frac{1.62}{.3771} = 4.3$$

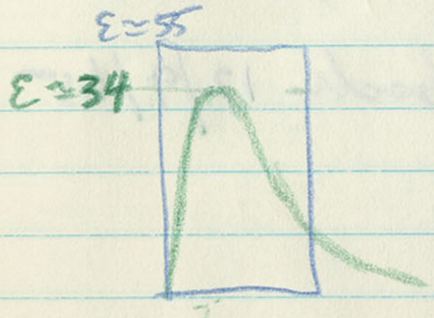
Add steady $\mathcal{E} = 1.75$ to 1
G_N goes from $5.3\, G_{SR}$ to $(5.3 + 1.75)\, G_{SR}$
$\therefore$ % increase of G_N is $\frac{1.75}{5.3} = 33\%$

However, in terms of resistance
$$\%\text{ decrease of } R_N = \frac{\left(\frac{1}{5.3} - \frac{1}{7.05}\right)100}{\frac{1}{5.3}} = \frac{18.85 - 14.2}{18.85}$$
$$= 24.7\%$$
which agrees with 24.8% originally obtained
from the steady state values in 1, with & without pert.

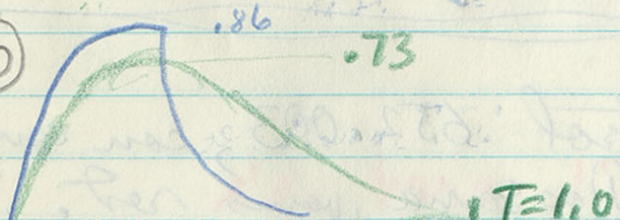


1st chart

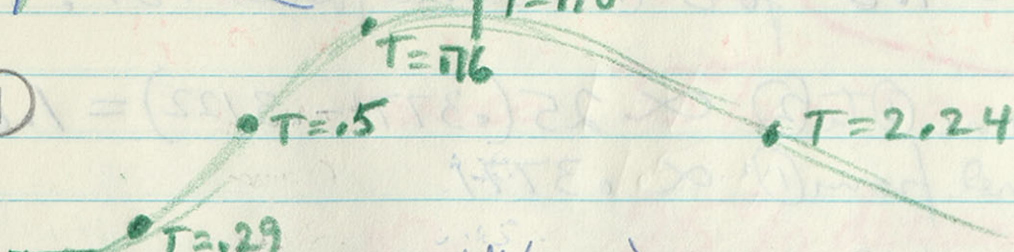
2nd chart was based upon 655.1 (10) with final sketch of 654.1 (10)



for (10)



for (1)



$$\frac{\tau}{V_{max}}\left(\frac{dV}{dt}\ \text{at half max}\right) = 2.0$$

for $\tau = 4\,\mu sec$ $\quad \frac{1}{V_{max}}\frac{dV}{dt} = 0.5\ \mu sec^{-1}$

for $E_r = 70\,mV$, $V_{max} = 7\,mV$ $\Big\}$ $\quad \frac{dV}{dt} = 3.5\ mV/\mu sec$

approx $\frac{1}{4}$ that for pt in (1)

12/7/65 Prepared to see K., Phil & Bob Burke tomorrow
Have 10 charts (654.1, 654.2, 654.5, 654.108
(652., 652.2 only, 655.1, 655.5, 656., 653.
Two plots (654.1 & 655.1 on small graph paper)
One yellow sheet covering p calc at bottom of p. 160
& Two large graphs traced from computer listings.

One presents 654.11 and 655.11 on common time & amplitude scales, comparing both ε size & time course & epsp time course
Also the following numbers

	Square ε		TRNS ε	
dimensionless $\frac{\tau}{V_{max}}\left(\frac{dV}{dt}\text{ at half way}\right)$	4.3		7.6	
for $\tau = 4$ msec, $\frac{1}{V_{max}}\frac{dV}{dt}$	1.1 msec^{-1}		1.9 msec^{-1}	
for $E_r = 70$ mV, $V_{max} = 7$ mV $\frac{dV}{dt}$	7.7 mV/msec		13.3 mV/msec	

Important to compare these with expt.

		$\tau = 4$ msec		$\tau = 4$ msec
also t/τ at 10% of max	.009	.04 msec	.023	.1 msec
at 90%	.206	.82 msec	.146	.6 msec
$\Delta t/\tau$ from 10% to 90%	.197	~.8 msec	.123	.5 msec
t/τ at peak	.25		.22	
$\Delta t/\tau$ from 10% to peak	.24	~1.0 msec	.20	~.8 msec
t/τ at rising $\frac{1}{2}$ max	.071		.072	
at falling $\frac{1}{2}$ max	.397		.598	
$\Delta t/\tau$ from rising to falling $\frac{1}{2}$ max	.326	~1.3 msec	.526	~2.1 msec

(3) I should check for $C = 0.65b$ in two kinds of series!

(A) Vary pert. location (1 to 5) with const ε_{TRNS} shape

(B) Keep pert. location at (3 say) & vary ε shape

~~more like temporal dispersion~~ (B.1 — vary TRNS ε duration
B.2 — vary Square ε duration)

See if any of these can be ruled out.

(4) Try supperimposing epsp & ipsp A. at same location
B. at different location

Bob finds they often sum surprisingly well

(5) Try superimposing a 1 mV epsp from pert in (8) with a 1.5 mV (3)

A. simultaneous

B. delayed

Bob has case of this kind which does less than 10%

(6) Phil Nelson says for anomalous rect. simulation attempt.
20 mV hyperpol causes R_N to be approx halved.
site of conductance change not known

12/8/65

Fruitful meeting with K., Phil & Bob Burke

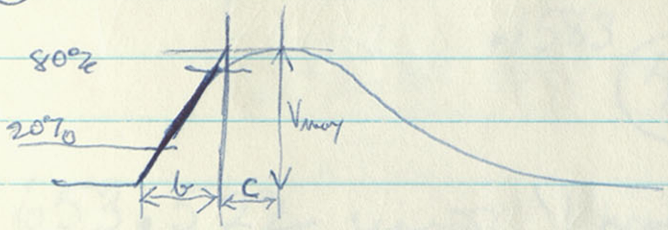
① Their fastest miniature and evoked epsp seem to be about twice as fast as my result for pert. in ①
This means that I should try faster transient $\mathcal{E}$.

Their fastest $\left(\frac{1}{V}\frac{dV}{dt}\right)$ is about 4 msec^{-1} maybe very rarely up to 5

Their shortest time to peak is about 0.5 msec, very rarely as little as 0.3
range is 0.3 to 1.5 msec
Correlation plot vs. peak height (300 μV to 1.5 mV)
shows almost complete lack of correlation
(round scatter)

---

② Bob Burke has been measuring as follows:



slope from 20% to 80% $\equiv \frac{dV}{dt}$

Define $b = \dfrac{V_{max}}{\frac{dV}{dt}}$

define $b+c$ = time to peak from foot intersection
which is measured from figure

Plot Time to peak versus b
i.e. $b+c$ versus b average slope found to $\simeq 1.65$

This indicates that $c = (0.65)b$ is a fairly constant characteristic of all his miniature & evoked epsp curves.

12/8/65 Computer Output put in pp. 155-156

654.560 J = 200 in (6) is not enough, gives ψ_{sp} = -.03103
peak in (6) is -.09344 at T = .49

whereas J = 80 gives -.02708 at
peak in (6) is -.0844

655.168 TRANS E on St St. initial driving pot in (6) is 1.15843
pert st st = -.323171; peak Q_{11} is 0.11597 at T = .62

655.128 initial driving pot. in (2) is 1.31218
peak Q_{11} = 0.131308 at T = .29

653.542 using J peak = 72.24 in (4)

st-st. control	.3771	at T = .44	.328921
pert "	.2188		.250274
	.1583		.078647
	42%		23.9%

653.522 using J peak = 20.46 in (2)

st-st control	.3771	at T = .26	.28
pert	.1464	.318896	.320117
	.2307	.195319	.196308
	61.2%	.123577	.123809
		38.8%	38.8%

655.551 simulation run with J = 146.47 in (5)
Not sufficient
peak = -.0457835 at T = .56

546 for $T^* = .04$

Plan ~~526~~ 522.100 series based on 556.1

& ~~625~~ 622 645 .100 series " " 655.1

But with $A_0 = 5.4366$
$\lambda_{ij} = 21.748$

in transient generator See p. 28

or could use even a little more, like

$A_0 = 6.0$ 6.25

$a = \lambda_{ij} = \frac{A_0}{.25} = 4A_0 = 24.$ 25.

then $t^* = \frac{1}{a} = \frac{1}{24}$ compared with previous $\frac{1}{10.87} = .092$

$t^* = \frac{1}{25} = .04$ See p. 170

$B^* = \frac{6.25}{2.718} = 2.3$

See p. 28

area up to 0.25τ is ~~fraction~~ $\{1 - e^{-6.25}(6.25+1)\}\Delta T$
$\{1 - (7.25)(.00193)\}\Delta T$
$\{1 - .014\}\Delta T$

i.e. 98.6%

12/8/65

653.162 using $\mathcal{E}_{peak} = 9.862$ in 6

st.st. .3771 $T = .62$ .337092

.3232 .327356

.0539 .009736

14.3% 2.89%

652.142 using $\mathcal{E} = 4.409$ in 4 $T = .34$ to .36

st.st. .3771 .324723

.3117 .309553

.0654 .015170

17.35% ~~7.75%~~

4.68%

652.162 using $\mathcal{E} = 9.677$ in 6 $T = .50$–.52

st.st. .3771 .332754

.3236 .323334

.0535 .009420

14.2% 2.83%

652.182 using $\mathcal{E} = 18.498$ in 8 $T = .76$

st.st. .3771 .342426

.3381 .336202

.0390 .006224

10.35% 1.82%

$$\int_0^{T_1} B\,dT = aA_0 \int_0^{T_1} Te^{-aT}\,dT$$

$$= aA_0 \left[\frac{e^{-aT}}{a^2}(-aT-1) \right]_0^{T_1}$$

$$= \frac{A_0}{a} \left\{ 1 - (aT_1 + 1) e^{-aT_1} \right\}$$

If $a = 25$ and $T_1 = 0.25$, then $aT_1 = 6.25$

And area from $T=0$ to $T=.25$ equals

$$\frac{A_0}{25} \left\{ 1 - (6.25+1) e^{-6.25} \right\}$$

$$= \frac{A_0}{25} \left\{ 1 - (7.25)(.00193) \right\}$$

$$= \frac{A_0}{25} \left\{ 1 - .014 \right\}$$

$$= 0.986 \left(\frac{A_0}{25} \right)$$

where $\frac{A_0}{25}$ is total area under curve

12/9/65 from p. 24, transient form is $\mathcal{E}$

$$\boxed{\begin{array}{l} B = aA_0 T e^{-aT} \\ \text{Max occurs at } T^* = \frac{1}{a} \\ \text{height is } B^* = A_0/e \\ \text{Area under curve} = B^* \cdot T^* \cdot e = \frac{A_0}{a} \end{array}}$$

So far, we have used $a = 10.87$, implying $T^* = .092$
$A_0 = 2.718$, $B^* = 1.0$
and area $= 0.25$
to agree with square $\mathcal{E}$
of unit height

here $B \doteq 29.6\,T e^{-10.87T}$

Now, we prefer to use $T^* = .04$, implying $a = 25.$
And we can choose either

or

$A_0 = 2.718$
giving $B^* = 1.0$ as before
but then
area under curve $= \frac{2.718}{25} = .1088$
which is $\frac{1}{2.3}$ of previous area

Choosing This

$A_0 = 6.25$
giving $B^* = 2.3$
but with area
under curve
equal 0.25, same
as before

8.6

7.

8.1

12/9/65

Setup 546.100 Series

Short Chain TRNS FIT. $T^* = .04$

$\lambda_{08} = 25. = \lambda_{8,7}$

Setup 546.110
546.120

~~Setup 646.001 Current Step Control~~

! Just noticed significant point in the 652, 653 & 656 series for perturbation in compartment 1

A pert causing epsp peak = 10% of driving pot. makes transient distortion = 10%

B pert for epsp peak = 20% causes transient distort of 20%

C pert for ipsp peak = 50% causes transient distort of 50%

Very simple rule, see if holds for sharper TRNS.

V_j/V_1 at T = 1.0

Compare Rel St. St. Values
100

$\varepsilon_j/\varepsilon_1$

$(12.5)(1.75) = 1.43 = \frac{1}{.7}$

$\left(\frac{.23535}{.29992}\right) = .784$ (2) 82.8

fits well

.784	2	82.8
.613	3	68.9
.475	4	57.6
.367	5	48.9
.285	6	42.0
.223	7	36.8
.179	8	33.1
.151	9	30.7
.137	10	29.5

Short Chain at T = 1.0			656.1 Series
1	.266367	100%	10%
2	.162717	61%	6%
3	.0980824	37%	3.6%
4	.0609097	23%	2.3%
5	.0440444	16.5%	1.8%

distortions

12/9/65

Now look for rule that applies to other pert. sites.
Consider three possible indices

(1) peripheral Σ volue factors
(2) " Vpeak " "
(3) peripheral st.st. values
or at T=1.0

The 653.1, 653.5, 654.1, 654.2, 654.5 series all agree approx that % distortions go down as follows

.1135 = 1/8.8 pert in 2 gives approx 79 % of pert in 1
.1446 1/6.9 3 61 %
.195 4 48
. 5
.352 6 3
7
.553 8
9
10

Checkback on 65.3 Sinusoidal current series begun 3/30/65
start p.109 of Book 6 & p.93 of Book 6
100 cps $\approx$ 628 radians per sec $\approx$ 2.5 per τ (of 4 msec) Then 3.14 per τ $=1/\tau=5$
in 65.300 series, use cpts 13 & 14 to generate sinusoidal

$\lambda_{13,14} = 2.5$
$\lambda_{14,13} = -2.5$ use π & get → period = 2τ
$\lambda_{0,13} = 2.5 - 1.$ (permitting $\lambda_{1,13} = 1.$)
$\lambda_{0,14} = -2.5$

$\therefore$ period $= \frac{6.283}{2.5} = 2.52\tau$

Start from earlier end values, to approach steady state & get ampl. decrement (mean) with distance

12/9/65

65.311

Setup 65.~~303~~.311

change 2.5 to 3.1416 = π
then period = 2τ

Delete plot, but leave in time factor = 8.
use no Kappas

1.0		
200.	~~.5~~ 1.	4. ~~10.~~
1.	5.0~~5~~	
200.	.05	20.

for all tr. cpts

Purpose is to find the steady state amplitude maxima in the several compartments. May need to use these results at max T as initial conditions for another run.

656.111 (B) Three Chains Mod 12/9/65
makes use of T = 1.0 values as initial values & also calls for st. st. values.

also put in 654.561

655.553

653.182
653.102 (10)

645.120 with T* = .04

12/9/65

652.102 using $\varepsilon = 55.$ in (10) $T = .88$

really should be 58.86

get

.3771	.346405
.3472	.341421
.0299	.004984
7.9%	1.44%

652.532 using $J = 28.424$ in (3) $T = .28$

.3771	.320117
.1906	.222806
.1865	.097311
49.4%	30.5%

654.112 find $\varepsilon = 58.8566$ in (10) causes epsp peak $= 0.010$ in (1) at $T = .88$

654.231 find $\varepsilon = 6.6$ in (3) makes epsp peak $= 0.02$ in (1) at $T = .29$

Put in late 12/10/65 probably went in Monday morning 12/13/65

546.130
546.140
65.311
646.110
646.120

12/10/65

656.111B Starting with I.C. from previous T = 1.0
Successful & also gets steady state perturbation.
$\mathcal{E} = 1.0456$ in 1 of short chain
causes TRNS distortion of 9.75% at T = .25
St. St. " " 26.4%

New Short Chain Series $T^* = .04$
Successful
a = 25.

546.110 found $\mathcal{E}$ peak = 1.751123 in 1 of short chain
causes epsp peak = .10 in 1 at T = .13

whereas 556.111 value of $\mathcal{E} = 1.0456$ in 1
gives epsp peak = .061376

546.120 found $\mathcal{E}$ peak = 4.2545 in 2 of short chain
causes epsp peak = .10 in 1 at T = .25

~~ther~~ peak in 2 was .1753 at T = .11

whereas $\mathcal{E} = 2.1086$ in 2 gives epsp peak = .053

65.311 Applied Sinusoidal Current Mod.
data exceeded 250 points ∴ did not run

655.009
Monitor Currents

Do first without a plot

would like
mv/msec

get directly
μV = fractional V per τ
times 70 to get mV per τ
times 14 to get mV/msec

Simulation run

For trans. pert. in cpt. 4, say

Let cpt. 16 monitor synaptic current

Then $\sigma_{16,4}$ 141

$\sigma_{16,12}$ 141

Dependence rel.

$\sigma_{16,12}$ 0 15 +1.

$\sigma_{16,4}$ 0 15 −1.

Make kappa 16 equal to .14 giving ~~mv/msec~~ / 100

Let cpt. 17 monitor loss current of pert. cpt. to neighbors & to leak

$\sigma_{17,5}$ ~~1 2 1.~~ 25.

$\sigma_{17,3}$ ~~1 1 1~~ 25.

$\sigma_{17,4}$ ~~−1.~~ ~~−26.~~ −51.

Let cpt. 18 monitor disturbing current at 1

$\sigma_{18,2}$ = 25.

$\sigma_{18,1}$ = −25.

12/13/65

It might be illuminating, for some of the simulations, to compare the true synoptic current from that artefactually calculated by phony formula, ala Eccles

1. true synoptic current at peripheral location.
2. true current from dendrites to soma.
3. pseudo current assuming single lumped cell.

Best to do ~~this~~ with the brief transient.

Got back computer output

655.553 needs larger time factor, got up to $J = 187.968$ in 5

654.561 needs larger time factor

653.102 opt 10 with $\Sigma = 33.64$ in 10 $T = 1.0$

control st.st.	.3771	$T=1.0$	.349915
pert "	.3487		.344460
	.0284		.005455
	7.53%		1.19%

653.182 with $\Sigma = 17.07$ in 8 $T = .86$

.3771	.345777
.3390	.339218
.0381 10.1%	.00656 1.90%

~~654.009~~

654.119

Anom Rect.

use $\lambda_{0,4} = 80.23$ which is supposed to reduce st st. 42.%

$Q_{14} = 1.$

use I.C. 1 − .2174844 −2.0

taken from 652.542

1	−.2174844
2	.1461837
3	.0873048
4	.01850643
5	.01567324
6	.01346698
7	.01179939
8	.01060378
9	.009832320
10	.009454154

$\lambda_{0,13} = 1.265$

$\lambda_{1,14} = -2.$

$\lambda_{0,14} = 2.$

$\lambda_{1,12}$ ~~= 1.21~~ 1

$\lambda_{0,12}$ 1

$\lambda_{13,1}$ 1

12/13/65

645.120 trans G $T^* = .04$

no fitting obtained

however $\mathcal{E} = 2.50$ in 2 with $T^* = .04$

gives ~~ppsp~~ peak $= .0589_2$ at $T = .16$

setup 645.121 ✓

655.149 ✓ } see p. 181 Monitor Current

655.169 ✓ }

655.554 rerun with larger time factor

645.100 } seeking peak time

645.180 } converted 653.000 decks

see p. 163 Setup 655.910 } TRNS E + J.

655.940 }

16 cpts

use $E_J = Q_{11} = .1$ & $J = \lambda_{0,15}$

$E_\mathcal{E} = Q_{12} = 1.0$ & $\mathcal{E} = \lambda_{0,16}$

then $\lambda_{1,11} = \lambda_{15,1} = -\lambda_{0,11} = (\lambda_{0,15})\, Q_{14}$

$\lambda_{1,12} = \lambda_{16,1} = -\lambda_{0,12} = (\lambda_{0,16})\, Q_{14}$

go to next notebook

12/15/65

Was out with gastrointestinal virus on 12/14/65

Got back following decks without listings,
These decks had been put in late 12/13/65

655.910
655.940 } TRNS EJ
645.100
645.180 } peak epsp peaks when $T^* = .04$
645.121 rerun
655.149
655.169 } monitor synaptic & other currents.
655.554 rerun
654.119 Anom Rect.
652.230

Also got back, without decks, the following listings that had been put in morning of 12/13/65 (see p. 179)

(12/14/65)

546.140 Short Chain TRNS Fit $T^* = .04$

~~Initial~~ $\varepsilon = 7.374$ in (4) gives epsp peak in (1) $= .051136$ at $T = .66$

peak in (4) is .2768 at $T = .11$

found $\varepsilon = 19.75142$ in (4) makes epsp peak in (1) $= .100565$ at $T = .66$

peak in (4) is .5386 at $T = .10$

546.130 Initial $\varepsilon = 4.1316$ in (3) gives epsp peak $= .05056$ at $T = .41$

peak in (3) is .1696 at $T = .11$

found $\varepsilon = 9.5246$ in (3) gives epsp peak $= .100094$ at $T = .41$

peak in (3) is .3343 at $T = .10$

period = 2τ, i.e. $T=1.0$ of step corresp roughly to half cycle
Actually, quarter cycle might be better!

see p 12 of book 8

100 cycles per sec = 628 radians per sec
= .628 " per μsec
≃ 2.5 " " τ for $\tau \simeq 4$ μsec
≃ 3.14 " " τ for $\tau \simeq 5$ μsec

Compare with p. 173 for $T = 1.0$

	rel. amplitudes
100	100
78.4	74.4
61.3	55
47.5	40.7
36.7	30
28.5	22.6
22.3	17.5
17.9	14.5
15.1	13.
13.7	12.35

Clearly the sinusoidal st. st. values run smaller than these $T = 1.0$ values

12/15/65

646.120 had a card error, need to be resubmitted.

646.110 Three chains, $T^* = .04$ with Current Step & with I.C. corresp to $T = 1.0$

unpert st.st. in cpt. 11 is .3435548
pert. st.st. in 1 is .2145063
.1290485 37.5%

peak in 18 = 0.0271983 ≈ .0272 at T = .13
Control value in 11 = 0.2766 at T = .13

distortion is 9.84%

Plotting scale here worked out quite well.

65.311 Applied Sinusoidal Current — Mod (12/9/65) See pp 174-176
did not call for plot this time.
period did come out 2τ

cpt. No.	time of peak	value	final value at T=6.0
1	5.25	-.0946717	+.0704596
2	5.30	-.0704230	.0412380
3	5.35	-.0520894	.0208313
4	5.45	-.0385643	.00726379
5	5.50	-.0285512	.00125572
6	5.60	-.0214255	-.00624141
7	5.70	-.0166013	-.00890328
8	5.75	-.0137474	-.0101573
9	5.85	-.0122875	-.0106523
10	5.85	-.0117207	-.0108001

$$\int \cos(n\pi x/L)\,\frac{\cosh\left(\frac{L-x}{A}\right)}{\cosh L/A}\,dx$$

$$\frac{e^{L/A}}{\cosh\frac{L}{A}}\int \cos(n\pi x/L)\left(\frac{e^{-x/A}+e^{x/A-\frac{2L}{A}}}{2}\right.$$

11/29/65 Phil phoned

we will get together next week

rate of rise of epsp with polarizing current

20 mV hyperpol.

~~rise~~ ~~1/5 resting pot.~~

Need resimulate 654.110 with more time for falling

Need to apply current step to these now

11/17/65

Slope of semilog plot.

Because ~~this~~ semilog plots are commonly used ~~to ex~~ in the analysis of decay transients, it ~~is~~ is important to point out that ~~a sum of exponentials does not~~ although a single exponential plots as a straight line, ~~a double exponential~~ the sum of two exponentials does not plot as two straight line segments.

$$\text{If } V = C_0 e^{-t/\tau_0} + C_1 e^{-t/\tau_1}$$

$$\cancel{\ln\{V - C_0 e^{-t/\tau_0}\} = \ln C_1 - t/\tau_1}$$

for large t, such that ~~the term on~~ $C_1 \exp(-t/\tau_1)$ is negligibly small, a plot of $\ln V$ versus t yields a straight line having a slope of $-1/\tau_0$.

For smaller t, a plot of $\ln V$ versus t is not a straight line, ~~but~~ and its slope does not give $-1/\tau_1$. ~~The method of peeling~~ However, if the slow exponential is extrapolated back to small values of t, and these values are subtracted from V, a logarithmic plot of this difference provides a straight line

of slope $-1/\tau_1$, because

$$\ln\left(V - C_0 e^{-t/\tau_0}\right) = \ln C_1 - t/\tau_1 \, .$$

~~However, it is possible to~~

~~If however, one wishes to discuss the slope of $\ln V$ versus t, one can make use of the following~~

$$\frac{d}{dt}(\ln V) = \frac{1}{V}\frac{dV}{dt} = \frac{-(C_0/\tau_0)e^{-t/\tau_0} - (C_1/\tau_1)e^{-t/\tau_1}}{C_0 e^{-t/\tau_0} + C_1 e^{-t/\tau_1}}$$

However, it is possible to discuss the slope of a logarithmic plot of a sum of exponentials. If

$$V = \sum_{n=0}^{\infty} C_n \exp(-t/\tau_n)$$

then

$$\frac{d}{dt}(\ln V) = \frac{1}{V}\frac{dV}{dt} = \frac{-\sum_{n=0}^{\infty} (C_n/\tau_n)\exp(-t/\tau_n)}{\sum_{n=0}^{\infty} C_n \exp(-t/\tau_n)}$$

which means that at any time, the slope is a weighted mean of the several $-1/\tau_n$, with weights equal to

$$W_n = C_n \exp(-t/\tau_n)$$

For the particular case of a sum of two exponentials,

~~if let this slope~~

~~if the slope~~

~~if the slope, $\frac{d}{dt}(\ln V)$, is designated s~~

~~Then we can write~~

The magnitude of this slope can be ~~designated~~ expressed

$$\cancel{s}\,k = \left(\frac{1}{V}\right)\left[(C_0/\tau_0)\exp(-t/\tau_0) + (C_1/\tau_1)\exp(-t/\tau_1)\right]$$

$$= \cancel{\left(\frac{1}{V}\right)\Big[} \quad \text{if } U = C_0\exp(-t/\tau_0)$$

$$\cancel{s}\,k = \frac{1}{V}\left[U/\tau_0 + (V-U)/\tau_1\right]$$

$$\frac{1}{\tau_1} = \frac{sV - U/\tau_0}{V-U}$$

$$\tau_0/\tau_1 = \frac{\cancel{s}\,kV\tau_0 - U}{V-U}$$